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FINAL REPORT

INFRARED REFLECTANCE SPECTRA FOR  
SELECTED PAINT PIGMENTS

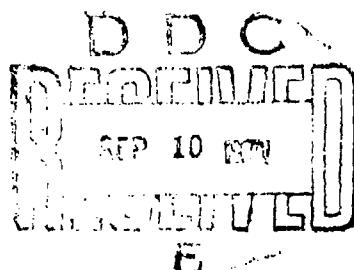
BY

MERRILL COHEN

AND

JOHN P. DONER

JULY 1971



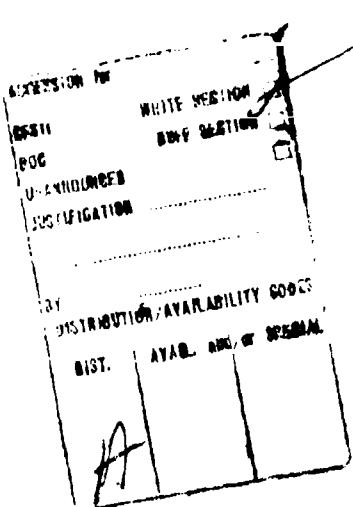
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### ABSTRACT

This report presents data on the near infrared reflectance spectra, 0.6-2.0 micron region, for 89 pigments in a wide range of colors. Pigments, both organic and inorganic, were selected for low infrared absorption and possible use in the design of military coatings with controlled infrared reflectance. The data obtained provides a basis for characterization of the pigments examined based on reflectance properties.

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## I. INTRODUCTION

Recent investigations on the development of dark colored Solar Heat Reflecting Coatings for military applications have demonstrated the inadequacy of fundamental data on the near infrared reflectance characteristics of paint pigments. While many publications report visible reflectance spectra, rarely is infrared data included.

The growing demand for the design of military coatings to provide visual camouflage for tactical situations as well as other special reflectance characteristics is a result of added functional requirements. Coatings are now being considered for their ability to reduce solar heat absorption, thereby providing increased operational reliability to electronic equipment exposed to solar heatings as well as personnel comfort. Coatings capable of defeating new detection devices are also being investigated and paints with special spectral characteristics have found recent use.

Initial work conducted in this area at the Coating & Chemical Laboratory began with the development of a solar heat reflecting olive drab paint. This first work was accomplished using a photocell reflectometer equipped with Wratten 87 and 89 filters.

While this early work provided a paint which was responsive to the then current requirements, the narrow spectral region in which the filter-photocell combination was sensitive, limited the development of optimum systems to meet current and future requirements. Therefore a program was initiated to measure spectral reflectance of coatings from 0.2-2.2 microns to provide the required data.

## II. DETAILS OF TEST

### A. Basic Formulations.

Reflectance data on pigments is generally reported based on the dry pigment pressed into a tablet. This method can result in high reflectance readings for pigments that, in fact, show considerable transparency when used in concentrations normally employed in paints. For this reason the pigments were studied at concentration levels representative of those used in coatings. The pigments were dispersed in a resin binder as shown in the basic formulations in Table I. The styrenated alkyd resin was chosen based on previous studies that showed it to have excellent transparency in the near infrared spectral region. The pigments investigated, Table II, included both inorganic and organic types.

The inorganic pigments were representative of those generally used in Army paints. They were made into Type I and II coatings of Table I depending on the oil absorption of the pigment with the higher oil absorption ones being made at the lower pigment concentration and vice versa. The two concentrations were required because the viscosity

increase which generally occurs in a coating as the oil absorption of the pigment increases can interfere with proper pigment dispersion. The organic pigments being still higher in oil absorption were made at the even lower pigment concentration of the Type III coating. All the paints were prepared by dispersing the pigment and vehicle in a porcelain ball mill for 18 hours using a 2:1 ratio of pebbles to paint.

B. Preparation of Test Specimens.

Test panels of 2024 Aluminum alloy (3 x 6 inches), were vapor degreased and solvent cleaned in accordance with Federal Test Method Standard No. 141, Method 2011. Black and white lustreless enamels conforming to Federal Specification 1T-E-516 were then spray applied to a dry film thickness of 0.9-1.1 mils to provide highly reflective and absorptive substrates for determining the degree of transparency of the pigment over the spectral range investigated. The test paints were then spray applied using a automatic spray apparatus over the black and white substrates to a dry film thickness of 0.9-1.1 mils and air dried 18 hours. A sample disc 1-11/16 inches was then stamped from each test panel and reflectance spectra determined from 0.6-2.0 microns.

C. Determination of Reflectance Spectra.

Reflectance spectra from 0.6 to 2.0 microns were determined using a Cary 14 Recording Spectrophotometer equipped with a 9 inch (26 Centimeter) integrating sphere reflectance attachment. Sample illumination was monochromatic at an angle of about 8° to the normal. Magnesium oxide was used as the reference standard.

D. Pigment Classification.

The spectrum for each pigment was examined over black and white substrates and classified according to optical type and reflectance as follows:

1. Optical type - Difference in percent reflectance over white and over black.

- |                 |         |
|-----------------|---------|
| a. Opaque       | 15      |
| b. Transitional | 16 - 30 |
| c. Transparent  | 30      |

2. Reflectance Level - Average percent reflectance over black and white substrates.

- a. High 55
- b. Medium 31 - 55
- c. Low 16 - 30
- d. Absorbing 15

### III. SUMMARY

This study provides data necessary for the proper selection of pigments to provide primary military colors with controlled IR reflectance. It will enable the formulation of coatings with color permanence in the visible range yet possessing special spectral properties for solar heat rejection or nonvisible spectral properties for other applications.

APPENDIX A

Preceding page blank

TABLE I - FORMULATIONS

	<u>Parts by Weight</u>			
	<u>Types</u>	I	II	III
Inorganic Pigment		354.6	254.2	---
Organic Pigment		--	---	110.8
Styrenated Alkyd, 50% N.V.		490.8	491.5	443.2
Xylene		151.1	251.0	443.1
Diethylamine		0.7	0.7	0.7
6% Cobalt Naphthenate		1.4	1.3	1.1
Antioxidant		1.4	1.3	1.1
Total Weight		1000.0	1000.0	1000.0
Total solids, %		60.0	50.0	33.3
Pigment on the total paint, %		35.5	25.4	11.1
Vehicle solids on total paint, %		24.5	24.6	22.2
Fineness of grind		7	7	7

TABLE II - Pigment Identification

Chemical Class	Spectra Figure No.	Average Reflectance		Diff.	Classification/ Type <sup>2</sup>	Formula Type <sup>2</sup> /	Code <sup>4</sup> /	Manufacturer/ Identification
		Black	White					
<u>Inorganics</u>								
Titanium dioxide	1 and 2	N/A	81	N/A	HO	I	A	Tipure R610
Carbon black <sup>3</sup>	1	6	N/A	N/A	A0	III	C	Superba carbon black
Iron oxide	3	7	45	38	AMT	II	B	Indian red R-RC9R
Iron oxide	4	12	13	1	AA0	II	C	Mapico brown 420
Cadmium sulfo selenide	5	21	43	22	LMT	I	D	Calco cadmium red L 74-5360
Cadmium sulfide	6	11	69	58	AHT	I	D	Cadmium orange 47-4700
Lead chromate	7	40	73	33	MHT	I	E	Chrome orange X-R19 CP light
Molybdate orange	8	53	74	21	MHTR	I	A	Molybdate orange YE69RD
Cadmium sulfide	9	22	71	49	LHT	I	D	Cadmium yellow lemon 47-4200
Lead chromate	10	42	75	33	MHT	I	A	Medium chrome yellow Y469D
Iron oxide	11	36	58	22	MHTR	II	C	Mapico yellow OK orange <sup>2</sup>
Lead chromate plus	12	13	44	31	LMT	II	A	Chrome green med Lt G-562-D
Chromium oxide	13	41	50	11	MMO	II	E	Chromium oxide green X-1134
Aluminum sulfo-silicate	14	6	45	39	AMT	II	F	Wera blue 8290
Ferric ferrocyanide	15	7	37	30	AMTR	II	E	Chinese blue A-1835 CP
Inorganic pigment	16	8	50	42	AMT	II	F	Aurora violet X-2262
<u>Organics</u>								
<u>Reds</u>								
Monoazo	17	6	18	8	AA0	II	G	Hostaperm brown FG 17-3000
Monoazo	18	11	73	62	AHT	II	G	Hostaperm red FGG 13-3350
Monoazo	19	17	71	54	LHT	II	H	Cromophthal scarlet A2G <sup>2</sup>
Monoazo	20	7	68	61	AHT	II	H	Cromophthal red 3 E
Monoazo	21	6	71	65	AHT	II	F	Barium lithol toner medium RT-250 <sup>4</sup>
Monoazo	22	5	47	42	AMT	II	I	Per carmine red FF toner 35-5001

See Page 11 for footnotes.

TABLE II - Continued

Chemical Class	Spectra Figure No.	Average Reflectance Over Black	White	Diff.	Classification <sup>1</sup> / Type <sup>2</sup>	Formula <sup>3</sup> / Type <sup>2</sup>	Code <sup>4</sup>	Manufacturer Identification
Monoazo	23	27	46	19	LMTR	III	A	Toluidine toner RT-386-4
Monoazo	24	25	45	20	LMTR	III	A	Toluidine toner RT-606-D
Monoazo	25	24	45	21	LMTR	III	A	Toluidine toner RT-232-D
Diazo	26	9	71	62	AHT	III	H	Cromophthal red GR
Diazo	27	7	75	68	AHT	III	F	Michigan red toner RT 1382
Diazo	28	15	68	53	AHT	III	I	Permanent red toner R-39-4001
Indigo	29	7	43	36	AMT	III	A	Thioindigoid maroon RT-552-D
Indigo	30	8	45	37	AMT	III	I	Anthrazen red violet RHP 49-4001
Isoindoline	31	11	49	38	AMT	III	J	Irgazine red 23LT
Oxynaphthanoic acid	32	7	47	40	AMT	III	F	Molara red 52
Oxynaphthanoic acid	33	21	72	51	LHT	III	G	Hostaperm vat red TG 13-4200
Perylene	34	17	70	53	LHT	II	K	Palogen red GS
Perylene	35	13	64	51	AHT	III	K	Palogen maroon G
Pyrazolone	36	25	78	53	LHT	III	L	Electra red pigment 14
Quinacridone	37	10	72	62	AHT	III	A	Monastral red RT-753-D
Quinacridone	38	6	79	73	AHT	III	A	Monastral red RT-743-D
Quinacridone	39	?	75	68	AHT	III	D	Cyanadur red 2C-8005
Organic red	40	18	71	53	LHT	III	F	Guyandot red toner cark RT-5940
Organic red	41	18	74	56	LHT	III	F	Duratone red toner red light RT-5928
Organic red	42	34	83	49	MHT	III	F	Dixie red medium RT-5340
<u>Oranges</u>								
Monoazo	43	19	65	46	LHT	III	L	Fanchon orange 'H-5
Diazo	44	14	72	58	AHT	II	L	Diane orange Y-25
Isoindoline	45	14	75	61	AHT	III	J	Irgazin orange R LT
Naphthalene tetracarboxylic acid	46	13	68	55	AHT	III	G	Hostaperm orange GR 2-4002
Dinitroaniline	47	16	73	57	LHT	III	A	Orange toner YI-419-0

See Page II for footnotes.

TABLE II - Continued

Chemical Class	Spectra Figure No.	Average Reflectance Over			Classification <sup>1</sup>	Formula Type <sup>2</sup> / Code <sup>4</sup>	Manufacture Identification
		Black	White	Diff.			
<u>Yellows</u>							
Monoazo	48	22	70	48	LHT	III	A
Monoazo	49	12	72	60	AHT	III	A
Monoazo	50	10	76	66	AHT	III	G
Diazo	51	9	74	65	AHT	III	H
Diazo	52	12	70	58	AHT	III	H
Benzidine	53	18	75	57	LHT	III	F
Benzidine	54	7	77	70	AHT	III	E
Anthrapirimidine	55	13	71	58	AHT	III	F
Anthrapirimidine	56	7	46	39	AMT	III	K
Anthraquinone	57	11	43	32	AMT	III	L
Isindolone	58	14	72	58	AHT	III	L
Quinacridone	59	6	40	34	AMT	III	J
<u>Greens</u>							
Monoazo	60	8	63	55	AHT	III	K
Nickel azo	61	9	42	33	AMT	III	A
Nitroso-naphthol	62	6	52	46	AMT	III	E
Phosphomolybdic acid	63	7	62	55	AHT	III	I
Phospho tungstic acid	64	8	71	63	AHT	III	E
Phospho tungstic acid	65	12	68	56	AHT	III	E
Phthalocyanine	66	8	66	58	AHT	III	E
Phthalocyanine	67	8	60	52	AHT	III	E
Phthalocyanine	68	10	62	52	AHT	III	A
Phthalocyanine	69	8	64	56	AHT	III	K
Phthalocyanine	70	9	61	52	AHT	III	K

See Page II for footnotes.

TABLE II - Continued

Chemical Class	Spectra Figure No.	Average Reflectance Over		Diff.	Classification <sup>1</sup>	Formu <sup>1,2</sup> Type <sup>2</sup>	Code <sup>4</sup> / Type <sup>2</sup>	Manufacturer Identification
		Black	White					
<b>Blues</b>								
Anthraquinone	71	9	62	53	AHT		III	E
Diazo	72	8	45	37	AHT		III	L
Indanthrone	73	10	64	54	AHT		III	H
Triphenylmethane	74	8	63	55	AHT		III	Cromophthal blue A4R
Quinone	75	7	60	53	AHT		III	F
Phosphotungstic acid	76	10	68	58	AHT		III	Alkali blue BT-7150
Phthalocyanine	77	11	45	34	AHT		III	Foil blue BT-9
Phthalocyanine	78	10	62	52	AHT		III	Marine blue toner X-2759
Phthalocyanine	79	10	64	54	AHT		III	Ramapo blue BP-173-D
Phthalocyanine	80	10	60	50	AHT		III	Zulu blue R-NC 4851
<b>Violets</b>								
Anthraquinone	81	8	66	58	AHT		III	A
Dioxazine	82	10	68	58	AHT		III	Platinum violet BP-273-D
Dioxazine	83	9	63	54	AHT		III	I
Dioxazine	84	9	67	58	AHT		III	Indofast violet lake B-4000
Indigo	85	11	66	55	AHT		III	I
Methyl violet	86	7	60	53	AHT		III	Perm violet M toner 47-3001
Phosphomolybdic acid	87	9	68	59	AHT		III	D
Phosphomolybdic acid	88	8	67	59	AHT		III	Cyanadur violet 55-8500
Organic violet	89	6	70	64	AHT		III	I
								I
								Anthrazen red violet RHP 49-4001
								E
								Methyl violet RHM 47-3612
								I
								Solar violet RTN 48-3612
								I
								Fast bordeaux violet B-11
								L

TABLE II - Continued

1/ Classification - Letter designation denotes reflectance over black; over white; and optical type. Example: AHT = Absorbing over black; high reflecting over white; and transparent optical type.

<u>Reflectance Level</u>		<u>Optical Types</u>	
A = Absorbing	0-15	O = Opaque	0-15
L = Low	16-30	TR = Transitional	16-30
M = Medium	31-55	T = Transparent	30
H = High	55		

2/ See Table I

3/ Included with inorganics as the black substrate.

4/ Pigment manufacturers.

<u>Code</u>	<u>Manufacturer</u>
A	E. I. duPont
B	Chas Pfizer
C	Columbian Carbon Company
D	American Cyanamid
E	Imperial Color and Chemical
F	Holland - Suco
G	American Hoechst
H	Ciba Corp.
I	General Aniline and Film
J	Geigy Chemical Corp.
K	BASF Corp.
L	Harmon Colors
M	Harshaw Chemical Co.

**APPENDIX B**

FIGURE 1  
BLACK & WHITE SUBSTRATES

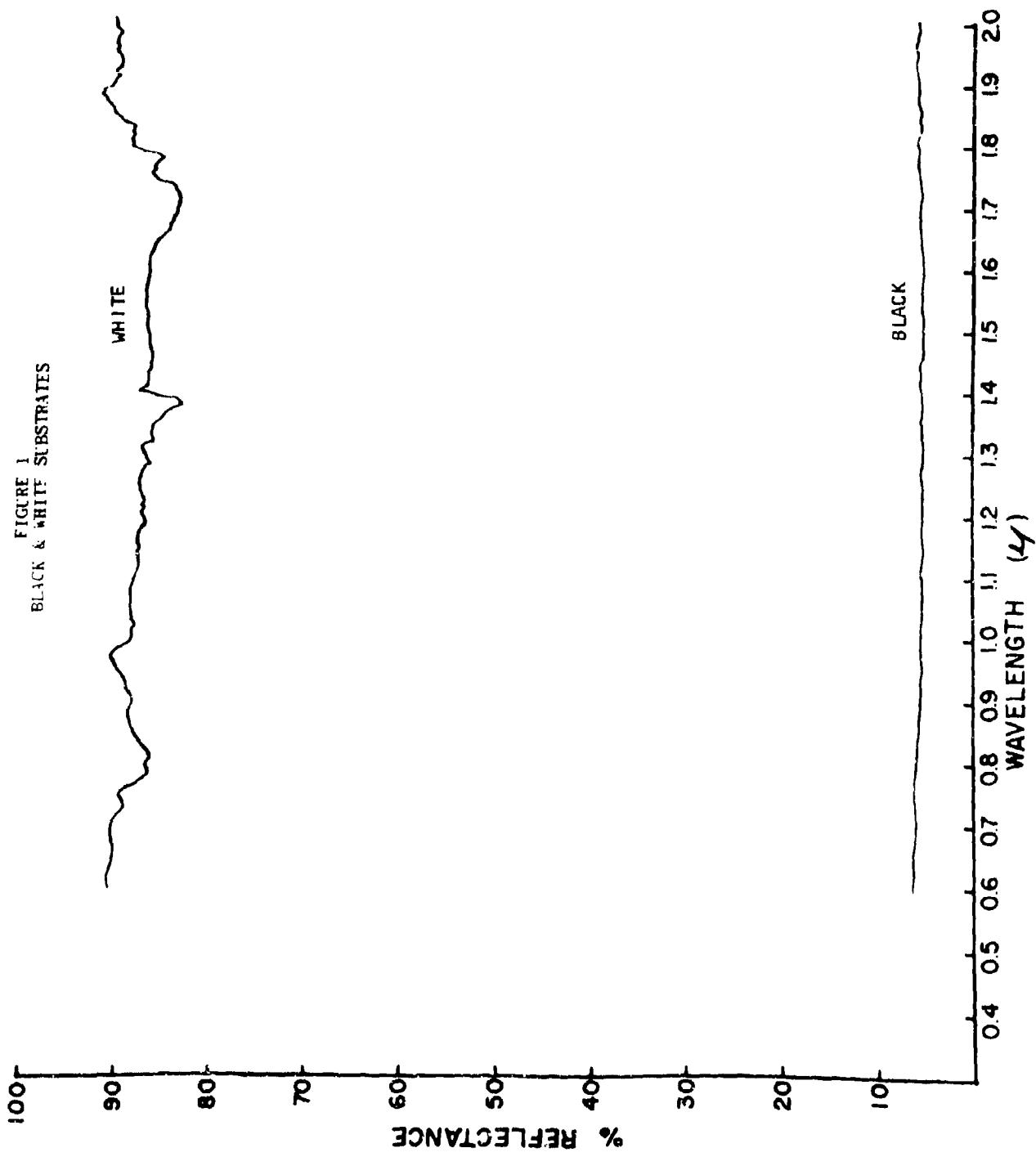


FIGURE 2  
TITANIUM DIOXIDE WHITE

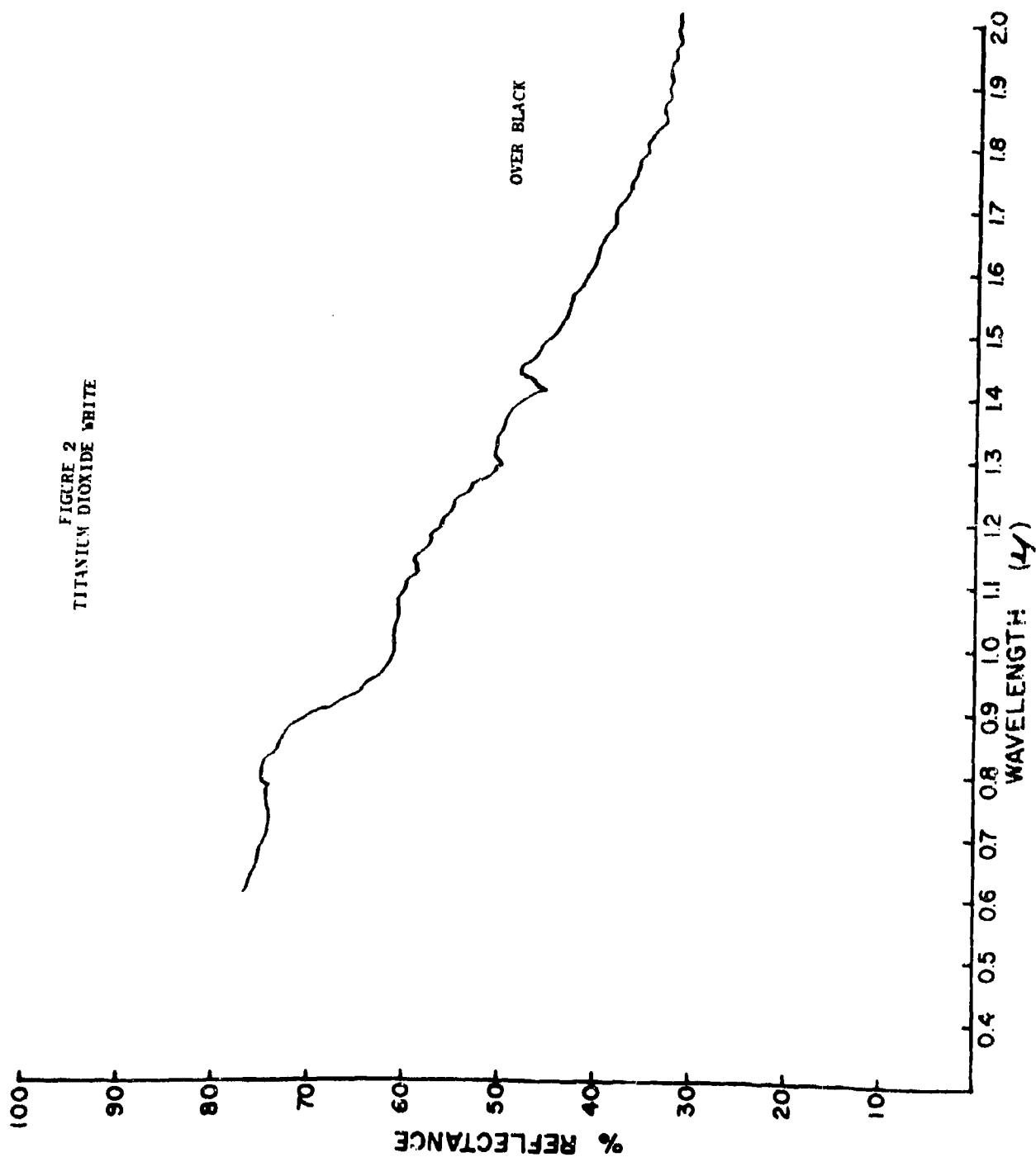


FIGURE 3  
IRON OXIDE P.E.

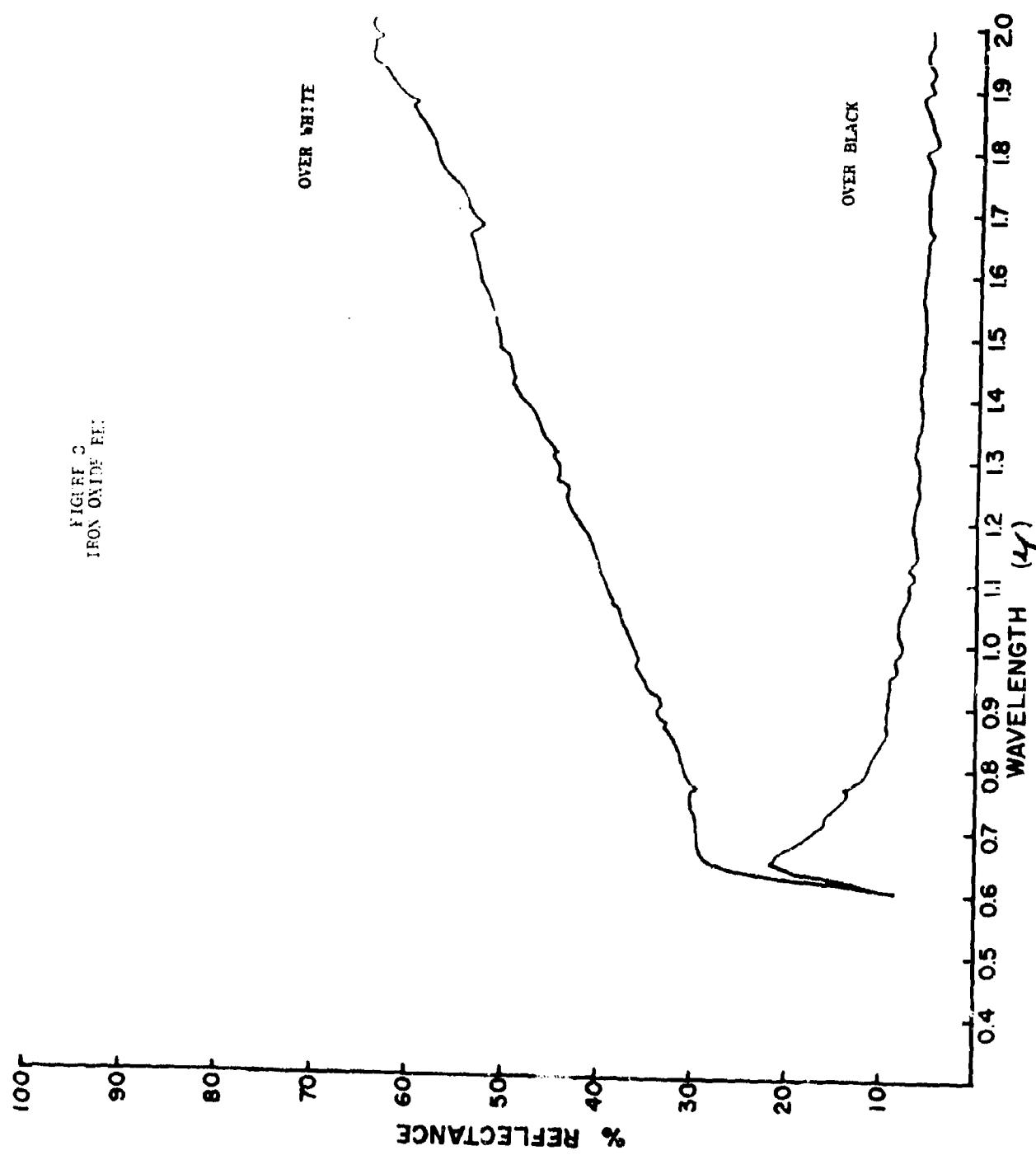
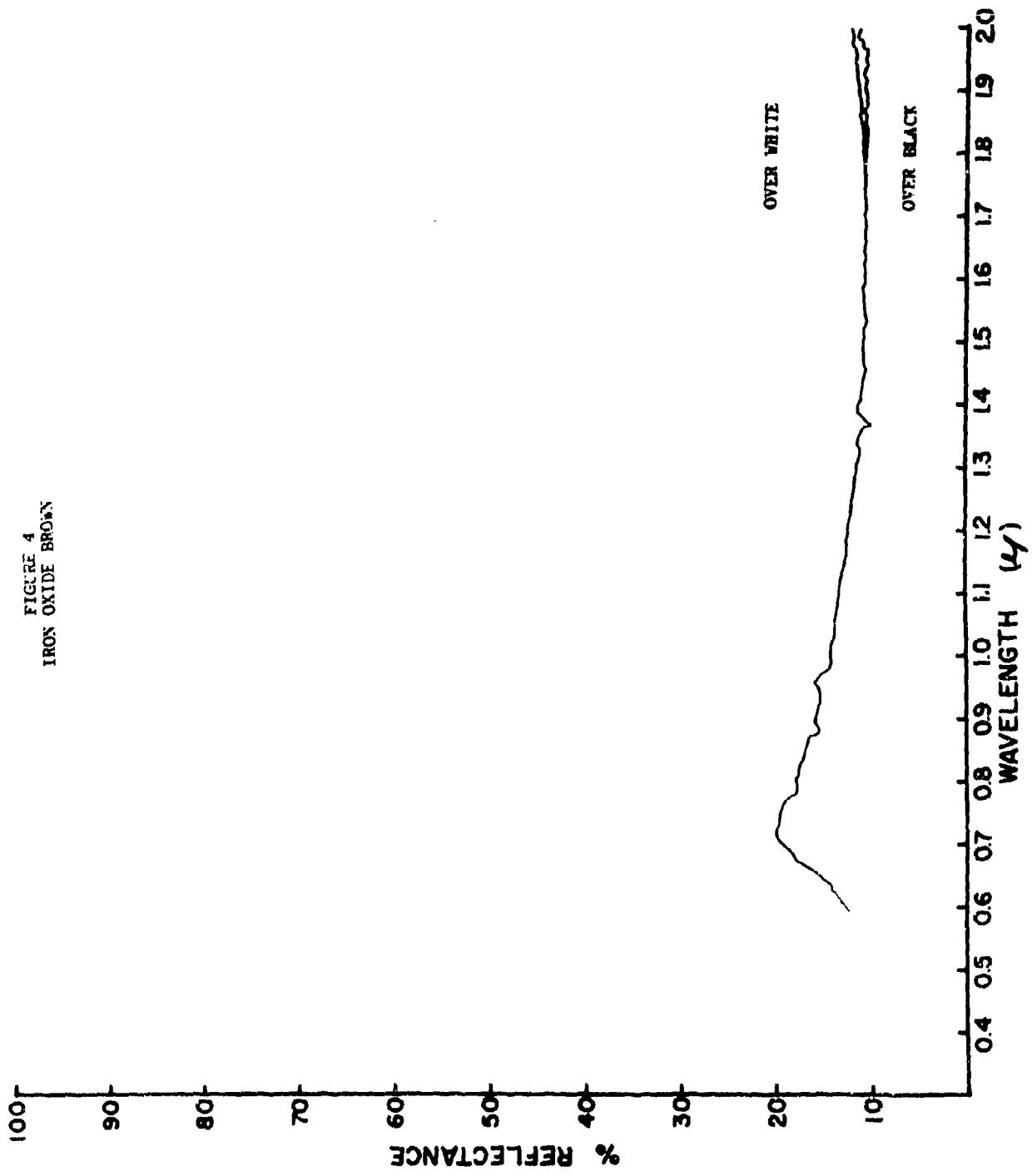


FIGURE 4  
IRON OXIDE BROWN



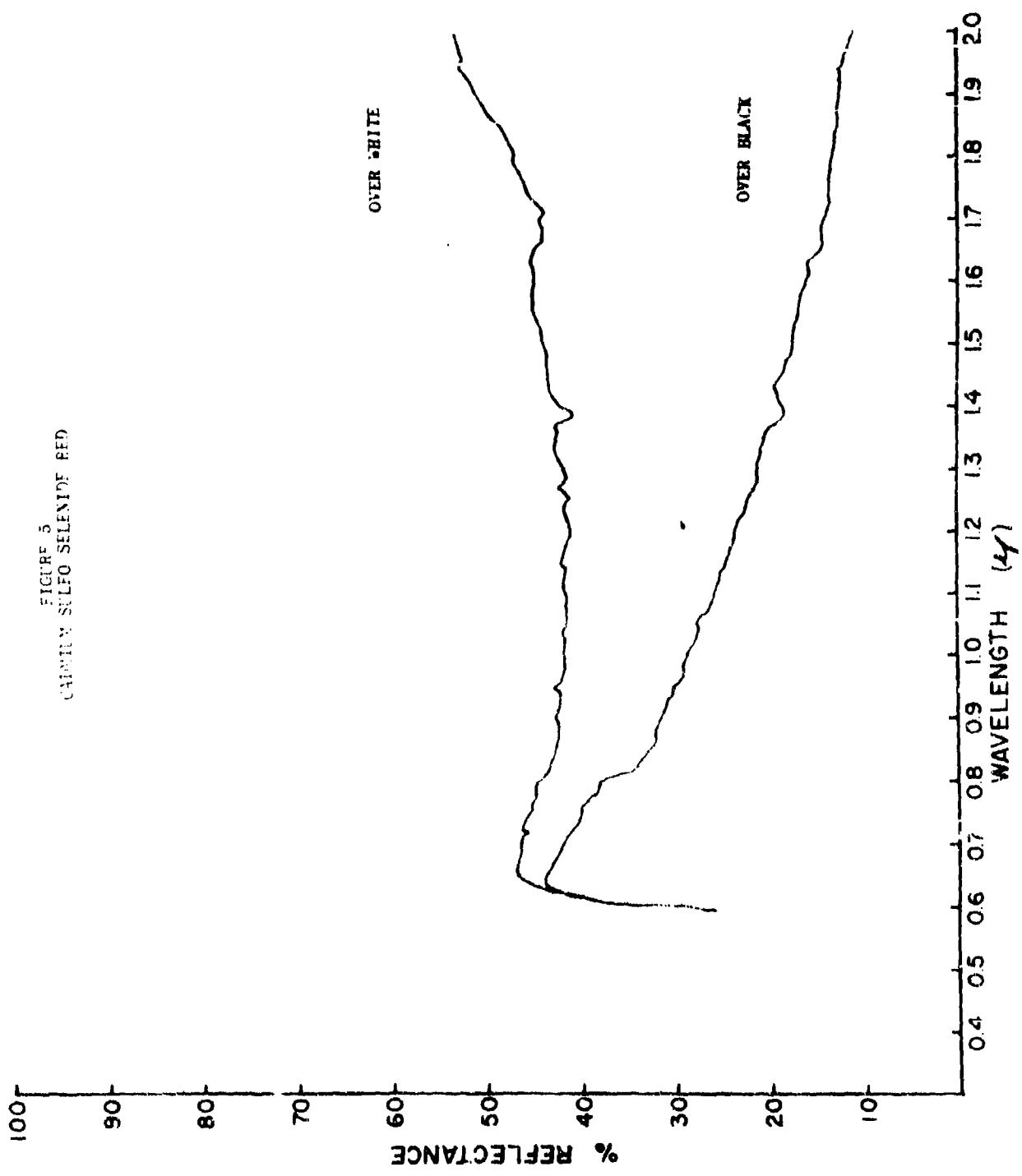


FIGURE 6  
CARBON STEEL OVER PAINT

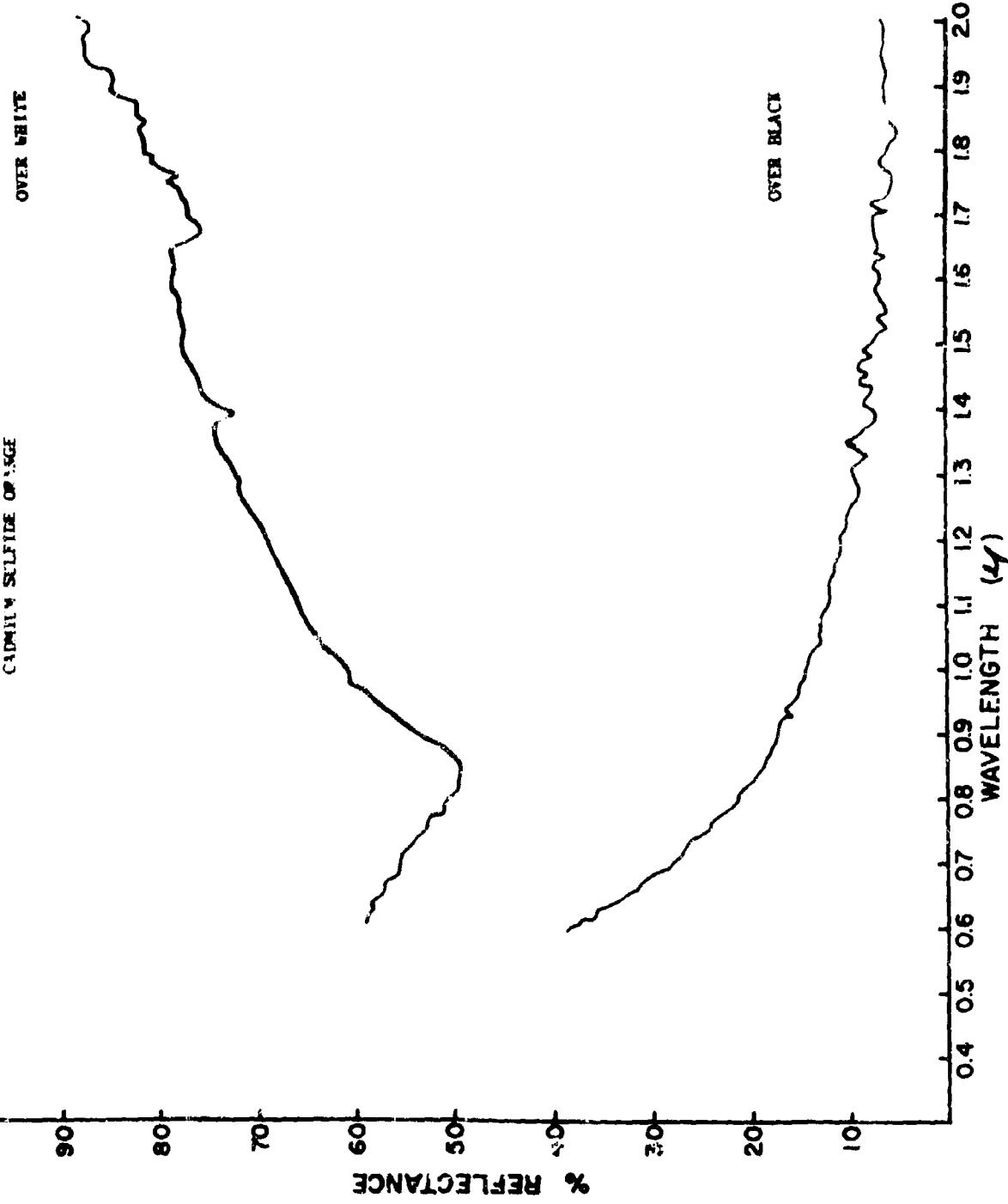


FIGURE 7  
LIQUID CHROMATE ORANGE

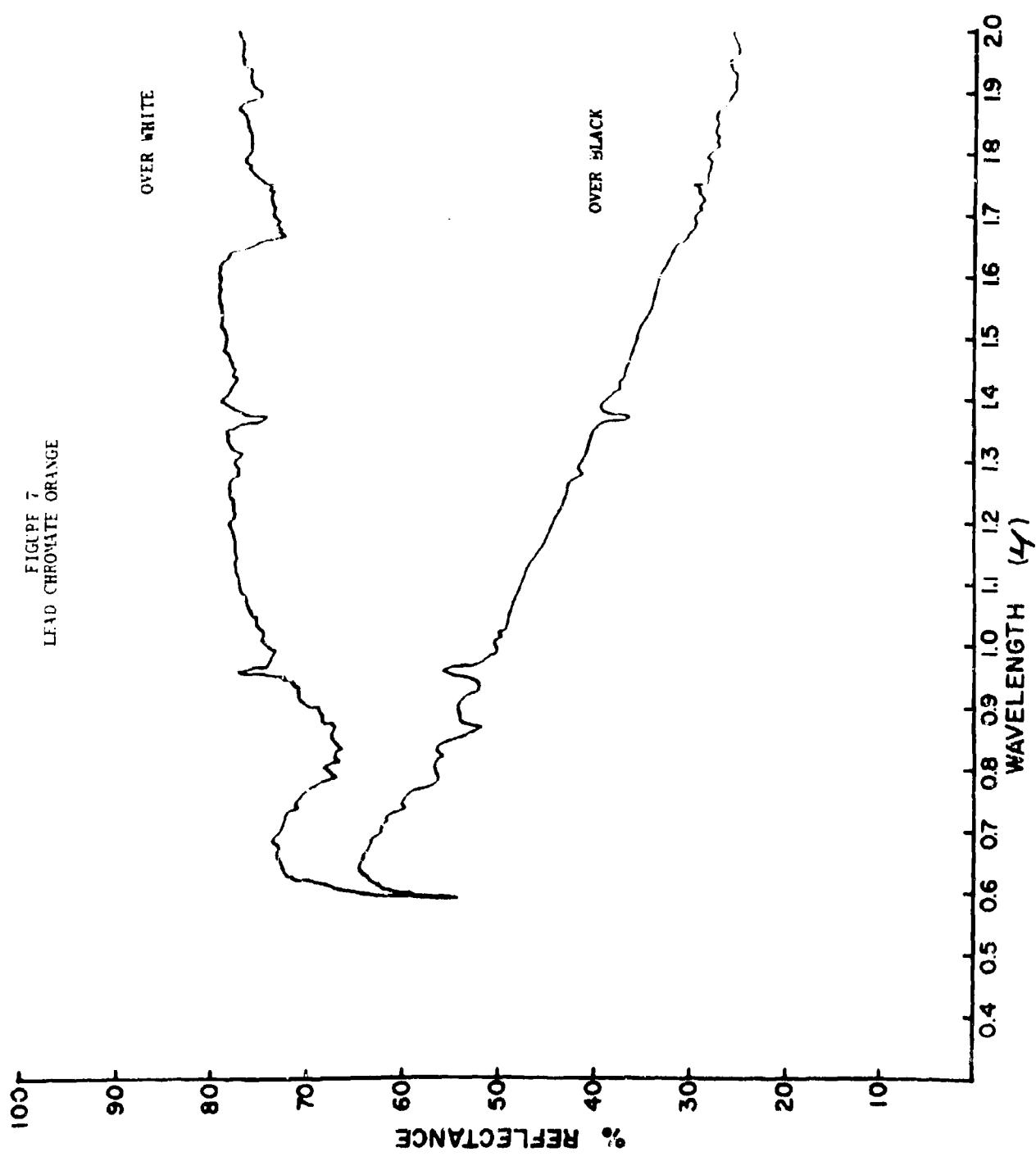
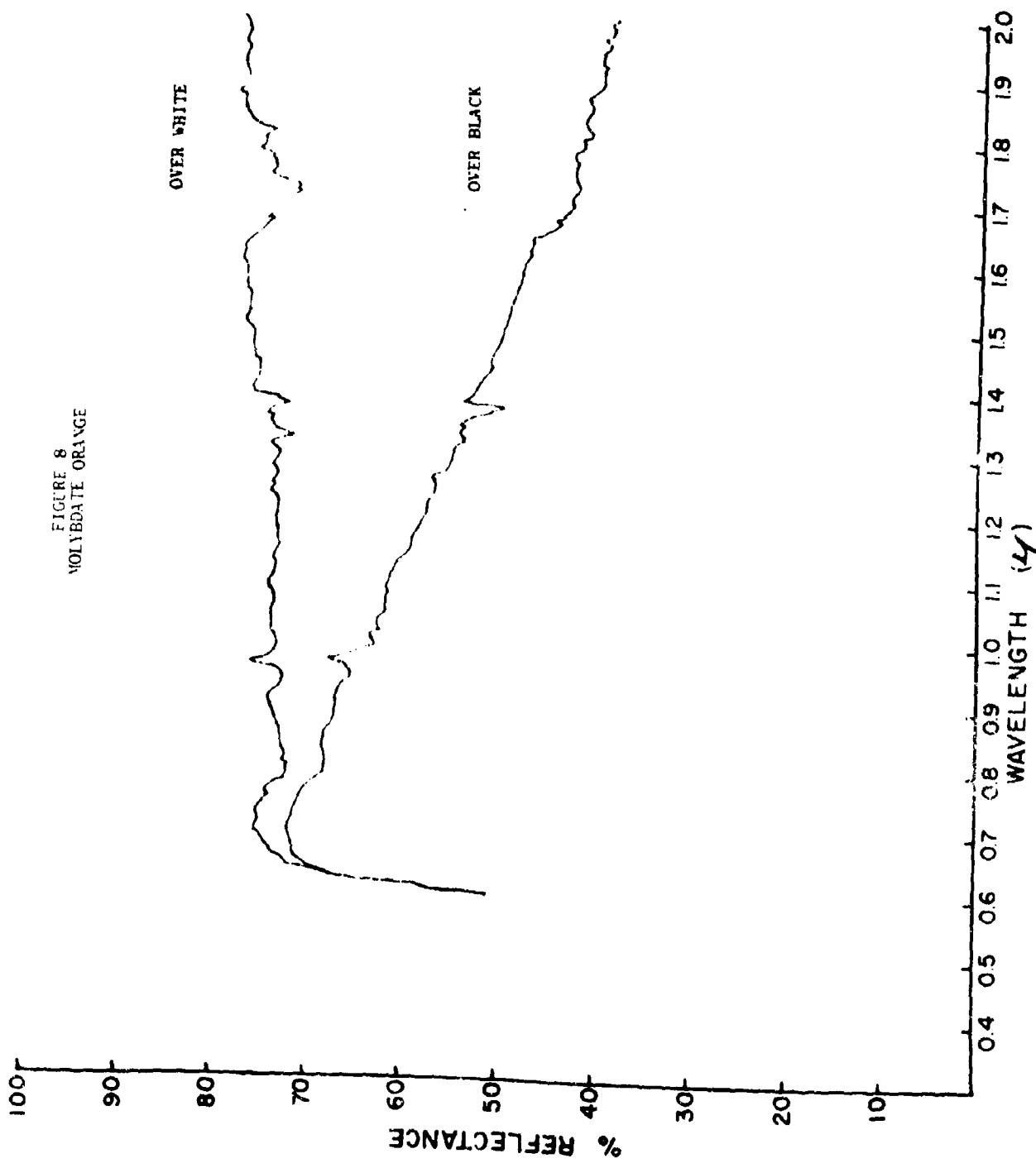


FIGURE 8  
POLYBDATE ORANGE



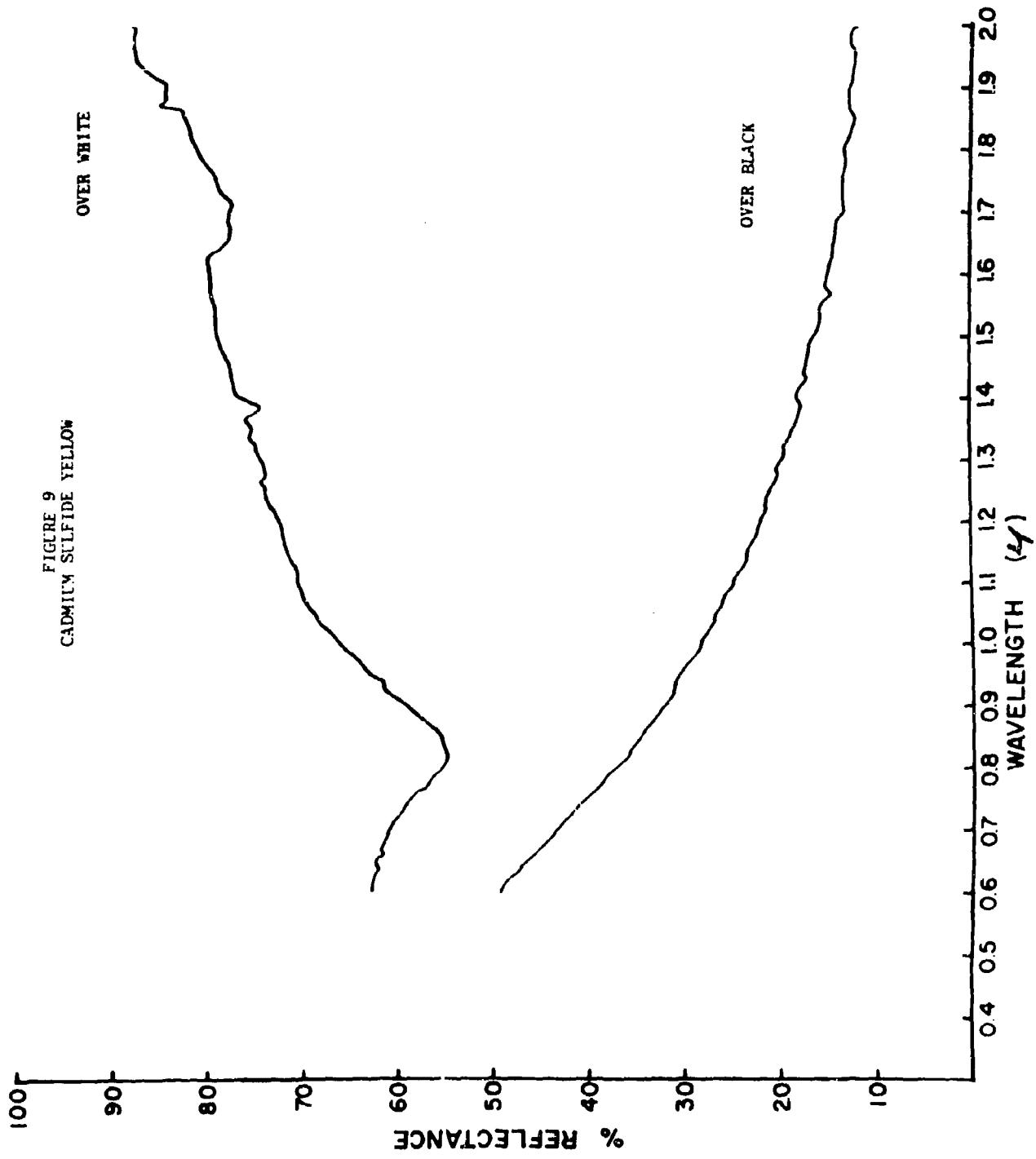


FIGURE 10  
LEAD CHROMATE YELLOW

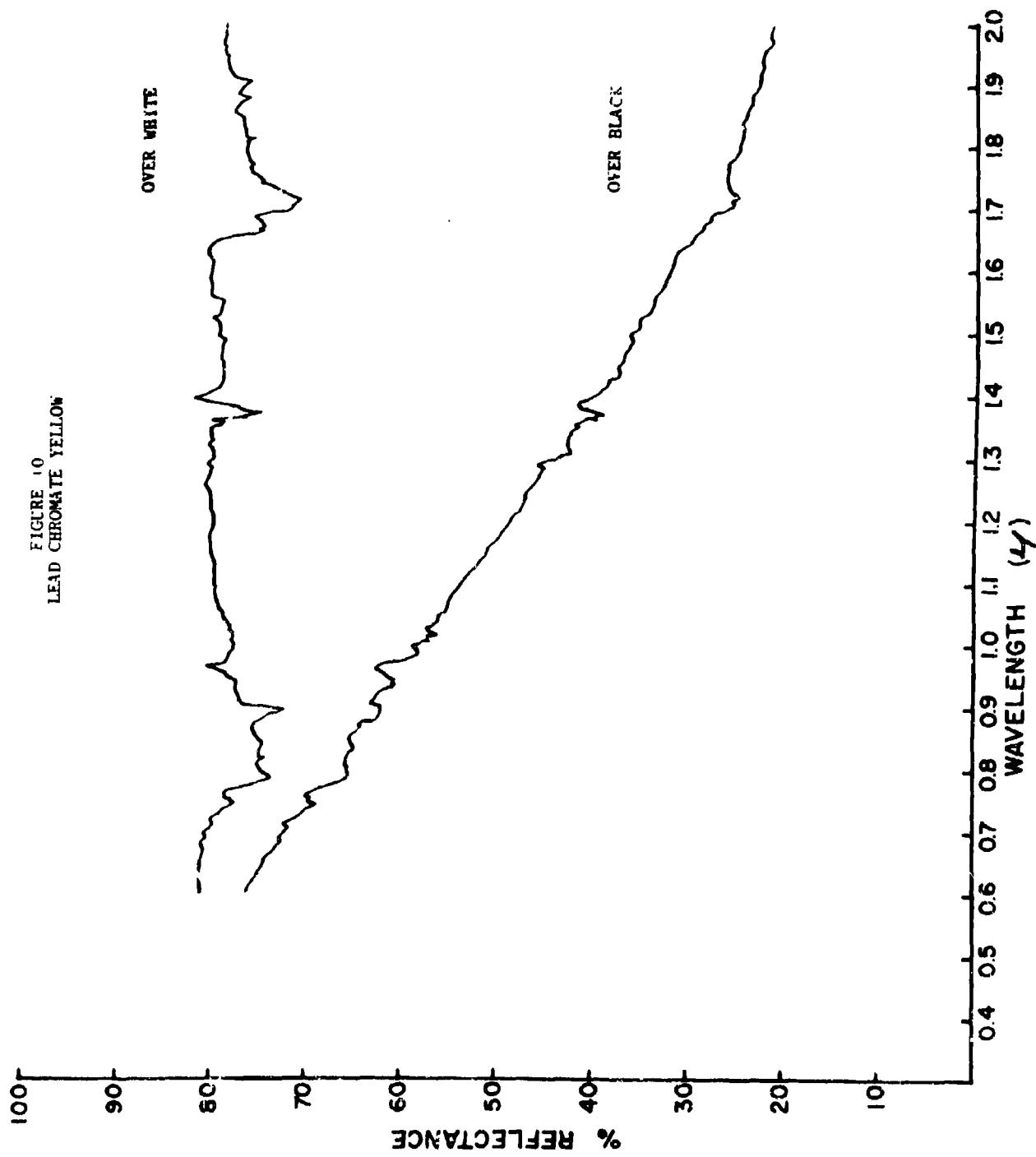


FIGURE 1  
IRON OXIDE YELLOW

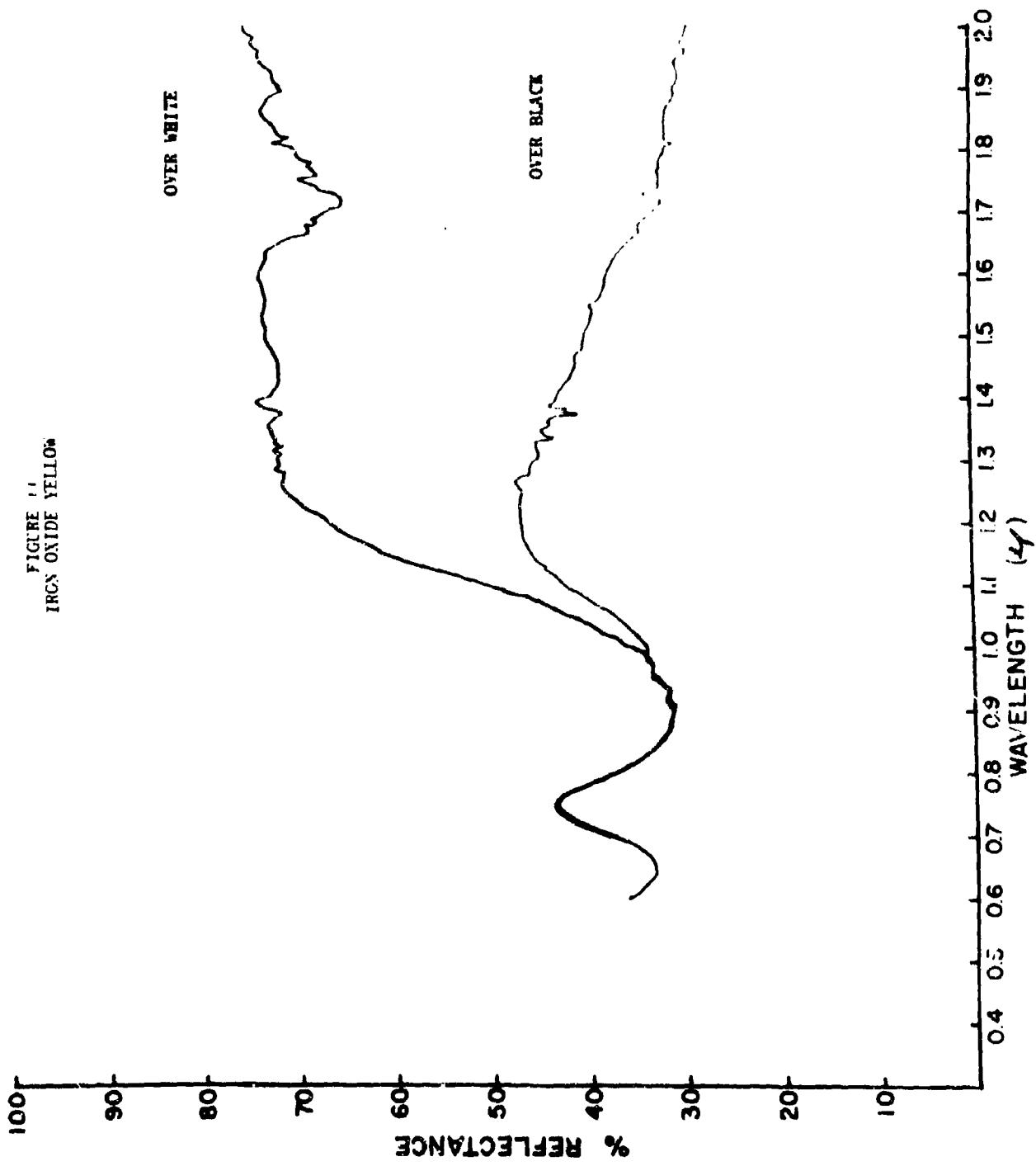
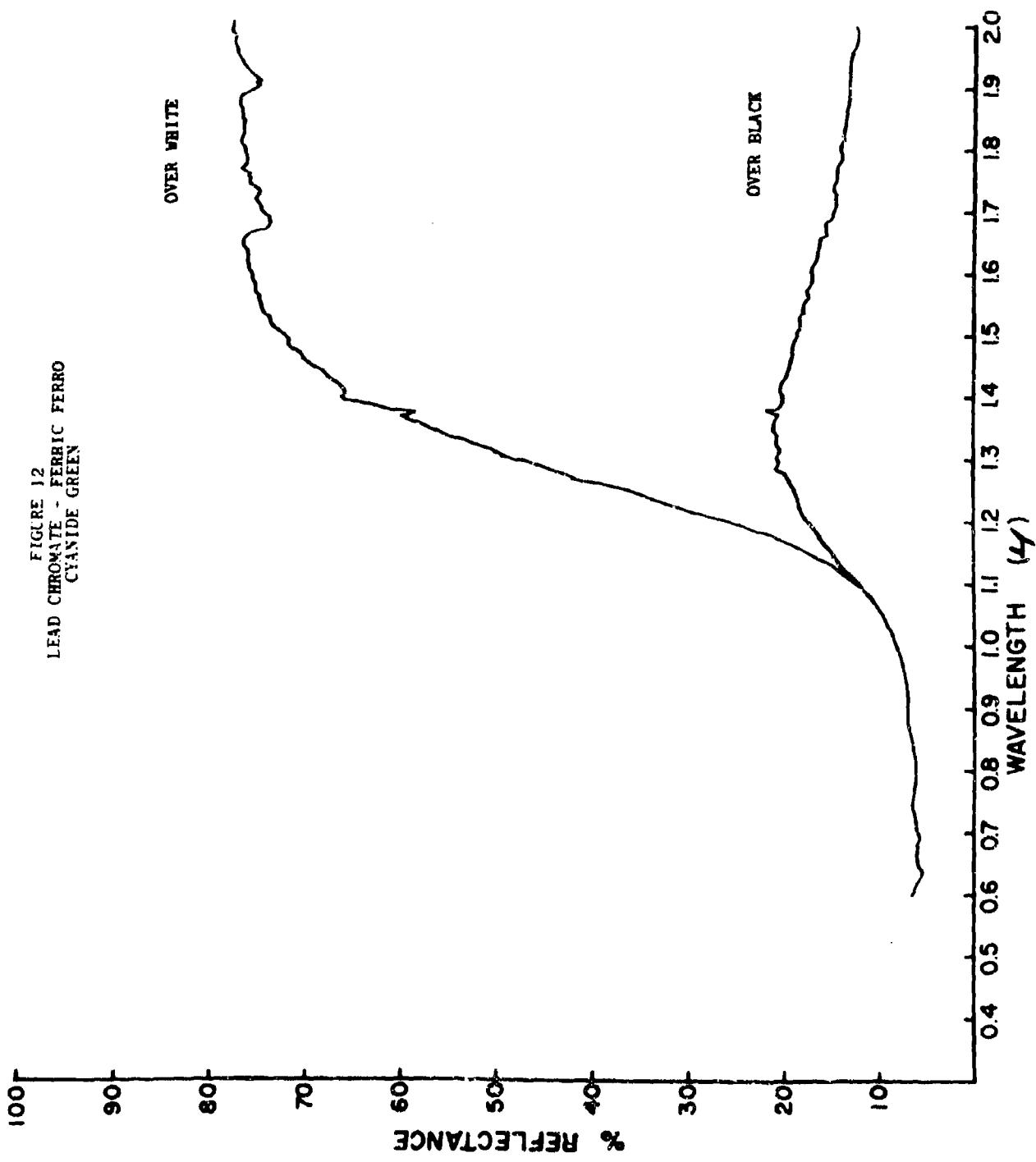


FIGURE 12  
LEAD CHROMATE - FERRIC FERRO  
CYANIDE GREEN



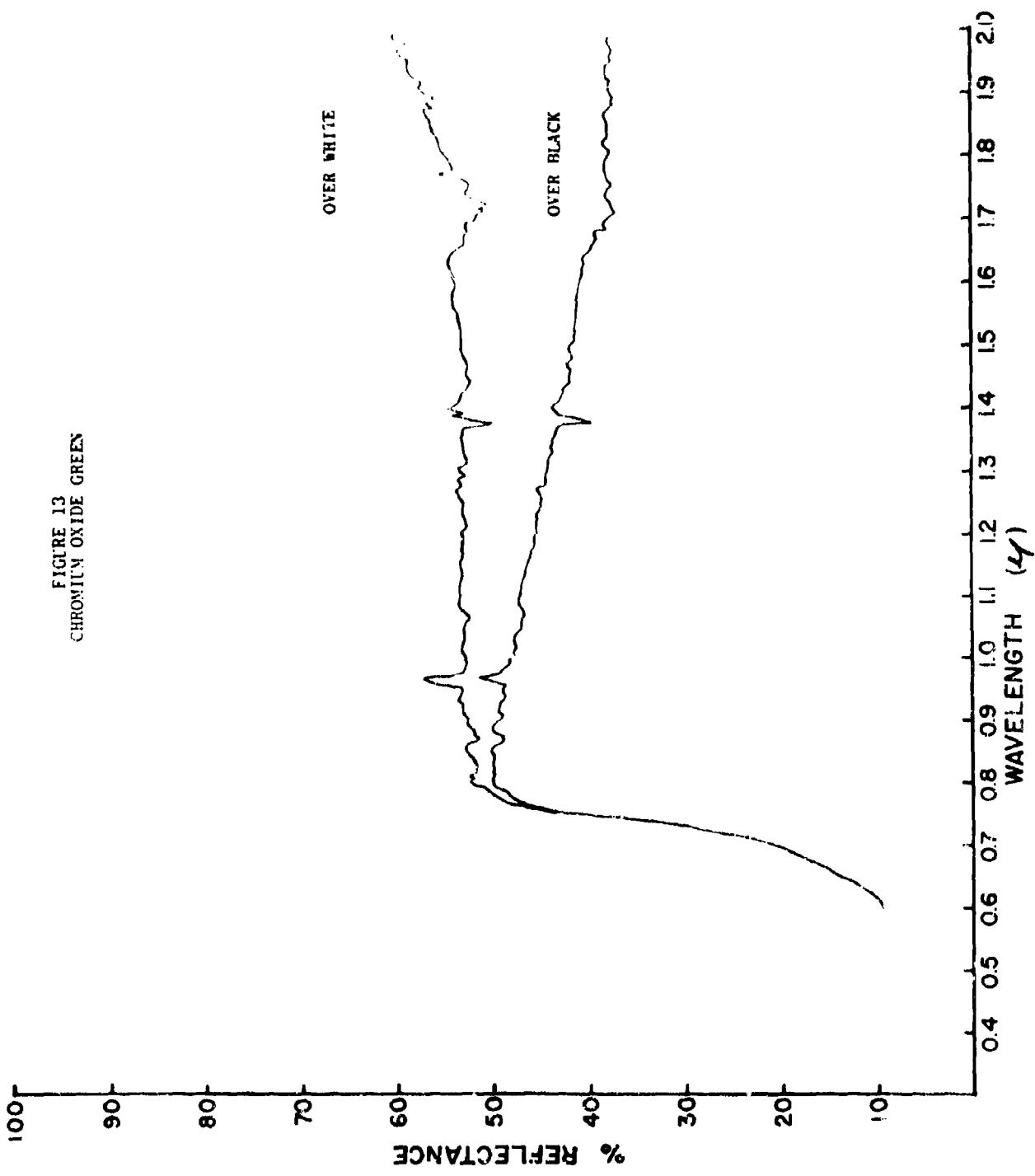
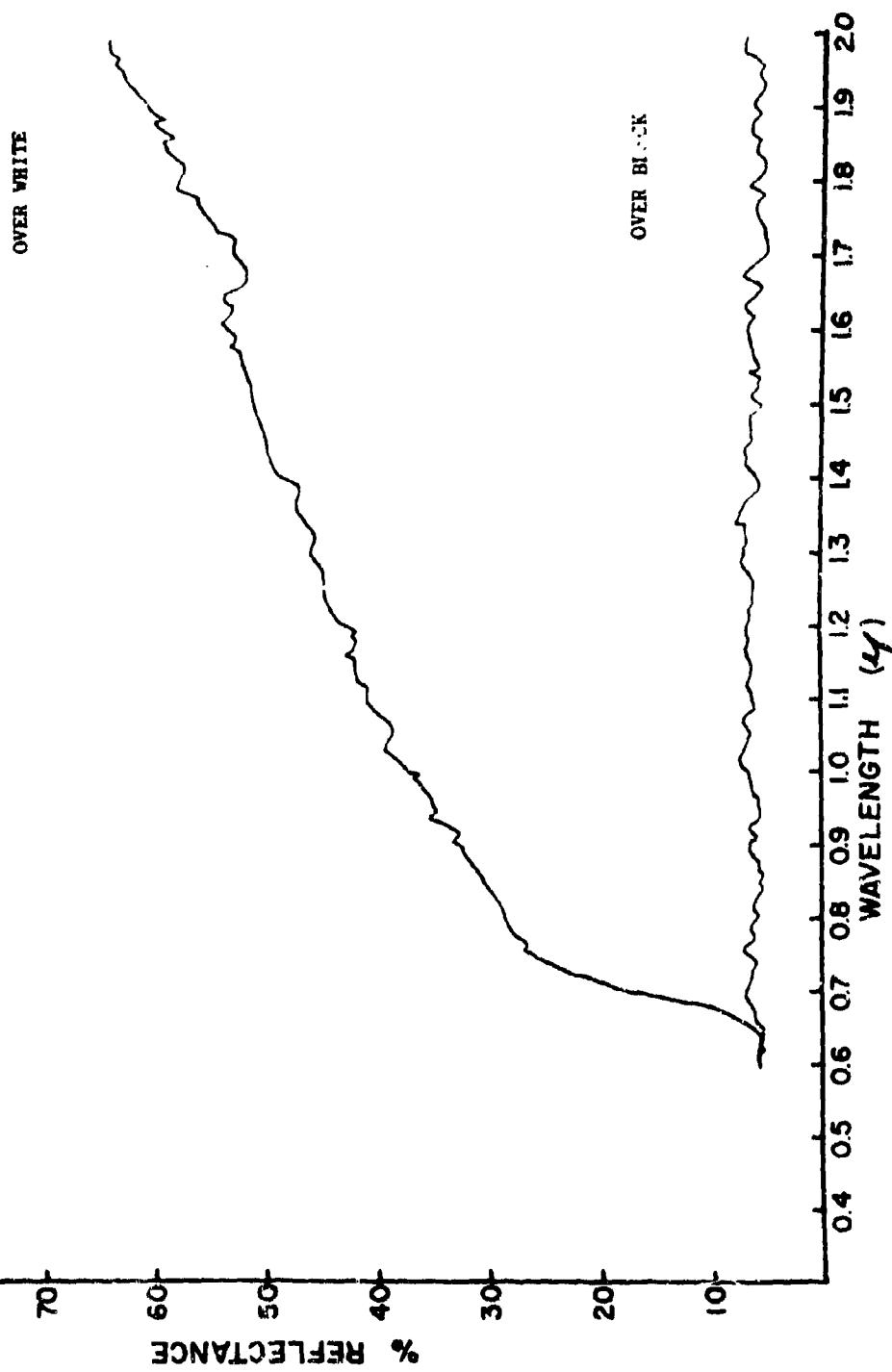


FIGURE 14  
ALUMINUM STILPHO SILICATE BLUE



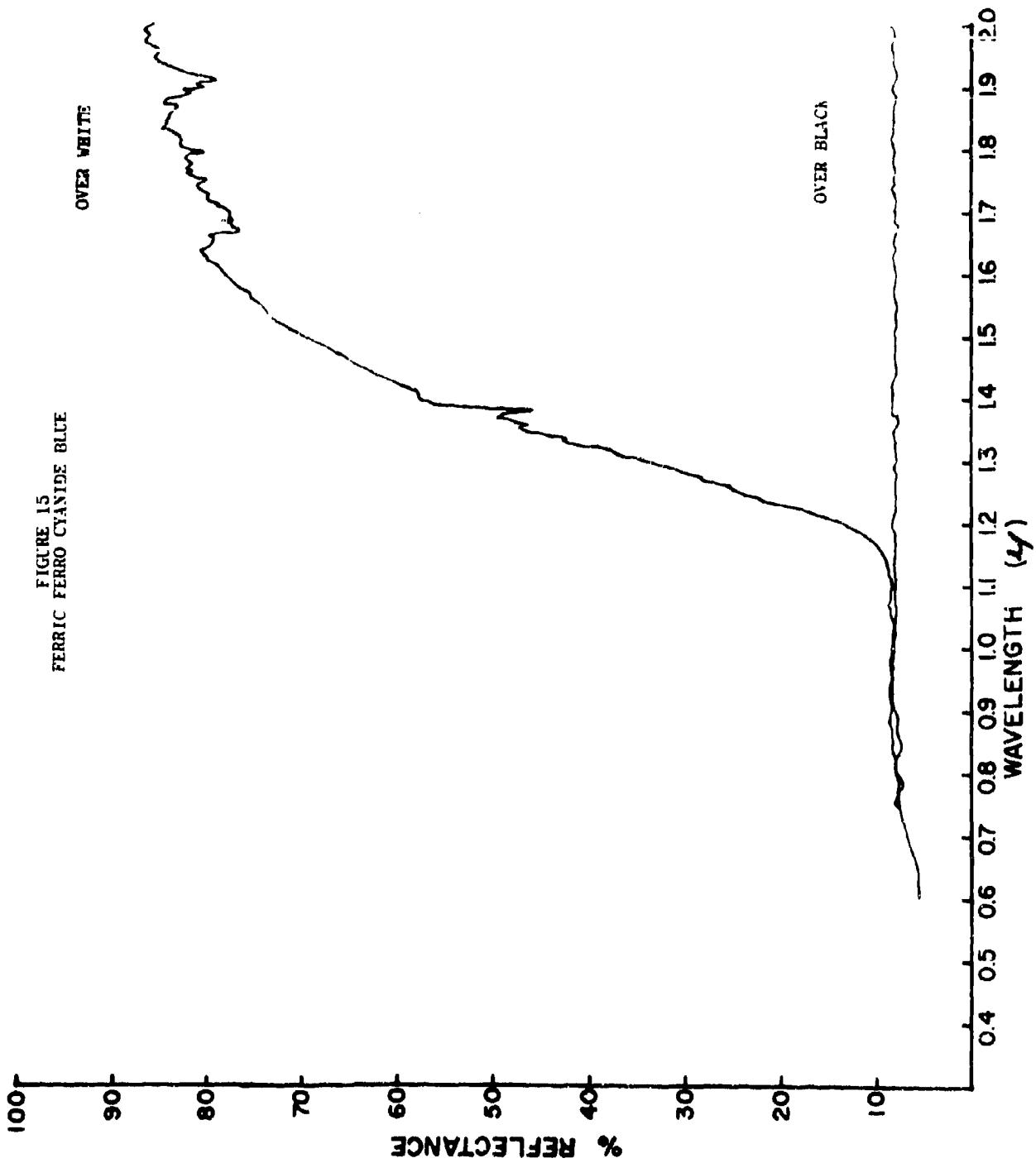


FIGURE 16  
INORGANIC VIOLET

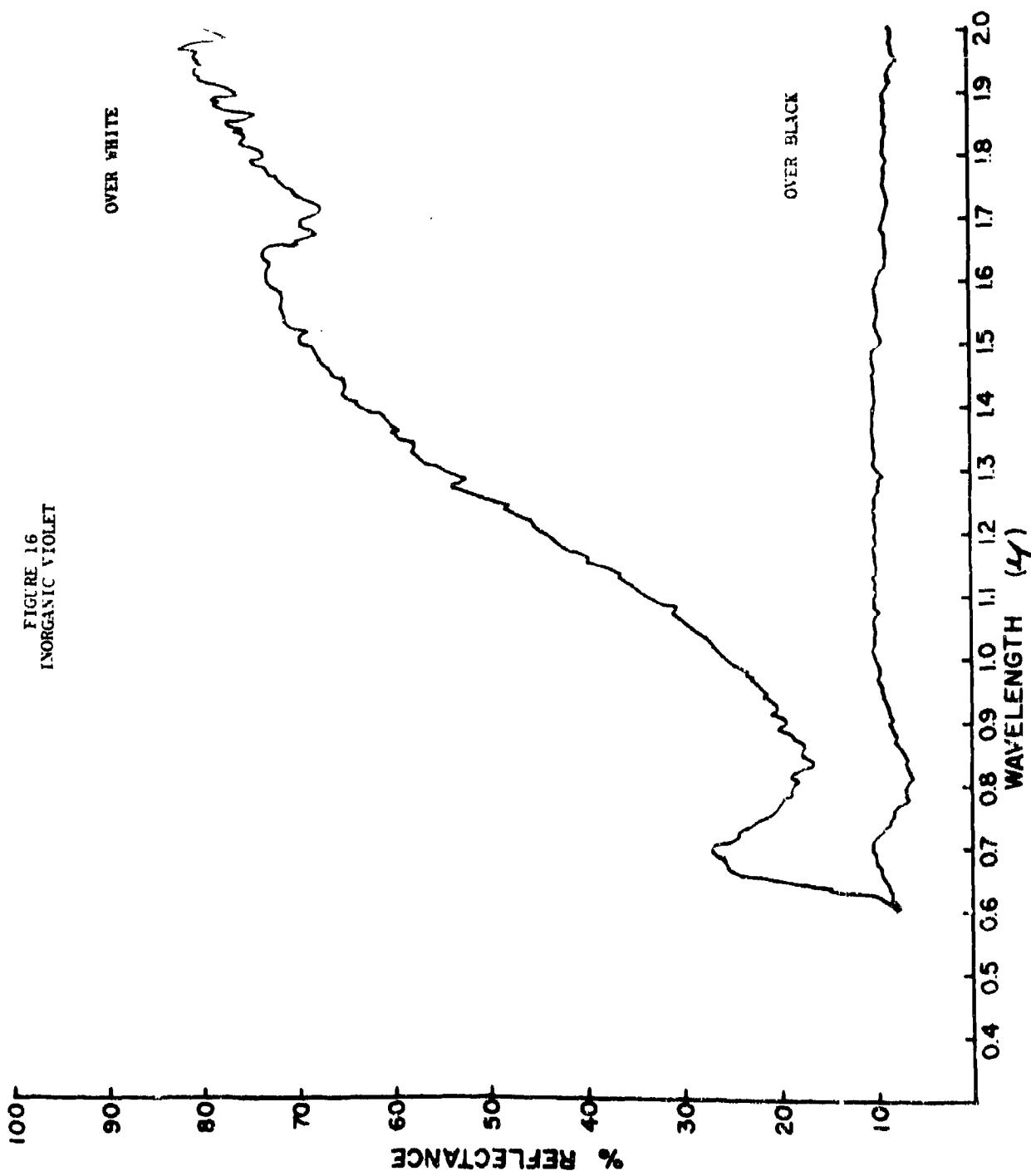


FIGURE 17  
MO:0420 RED

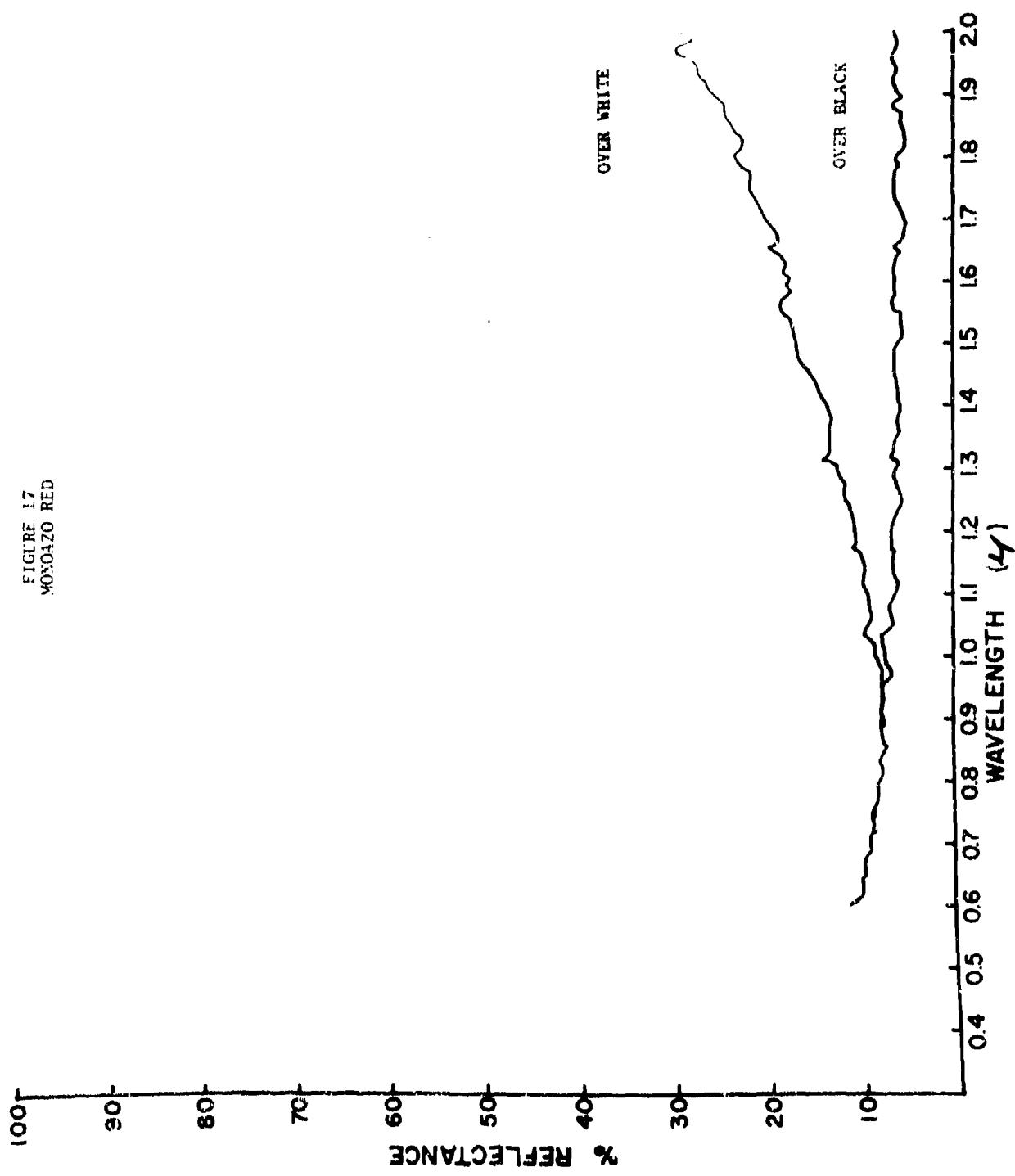


FIGURE 1.6  
MONOAZO RED

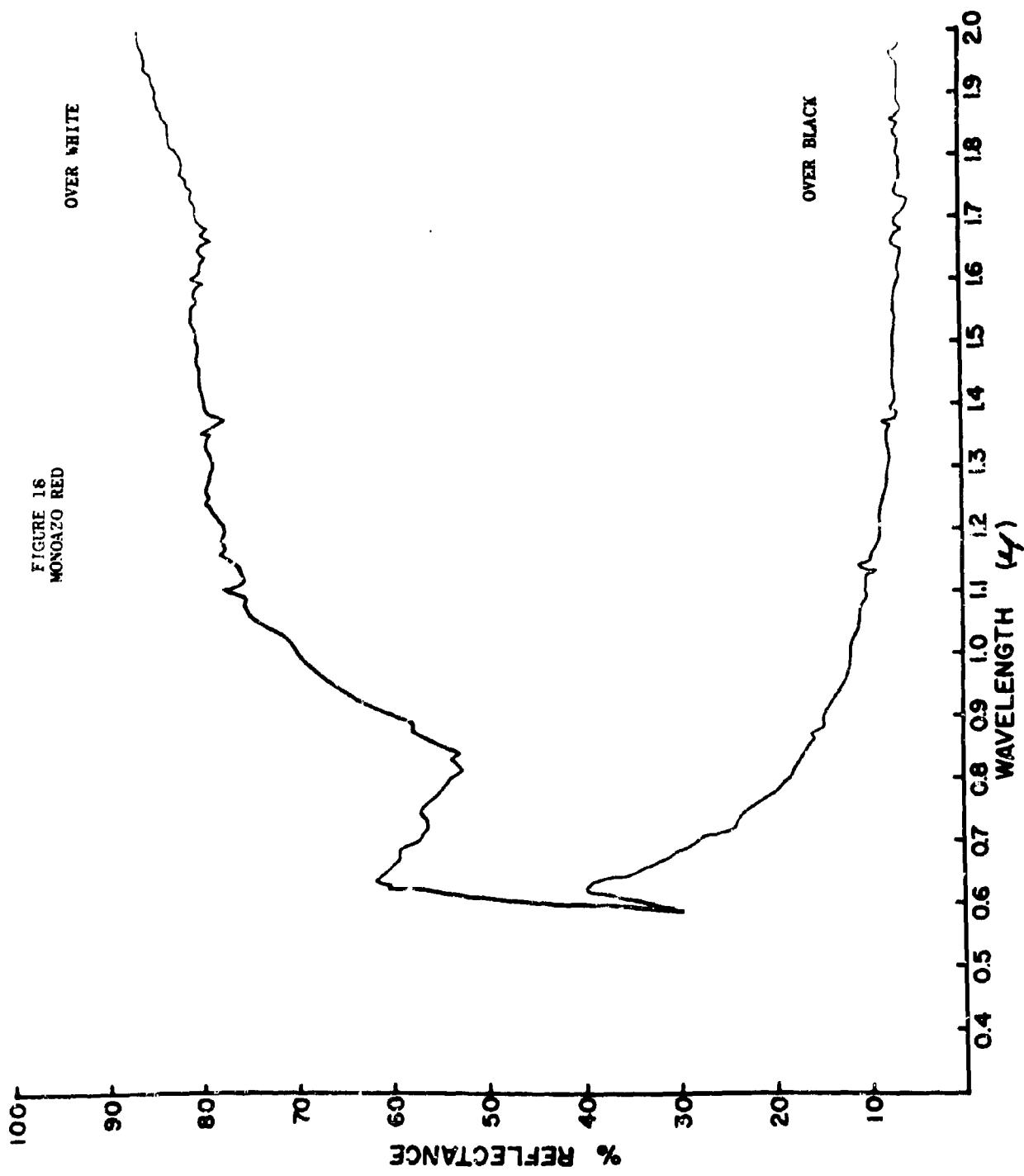


FIGURE 19  
MONOAZO RED

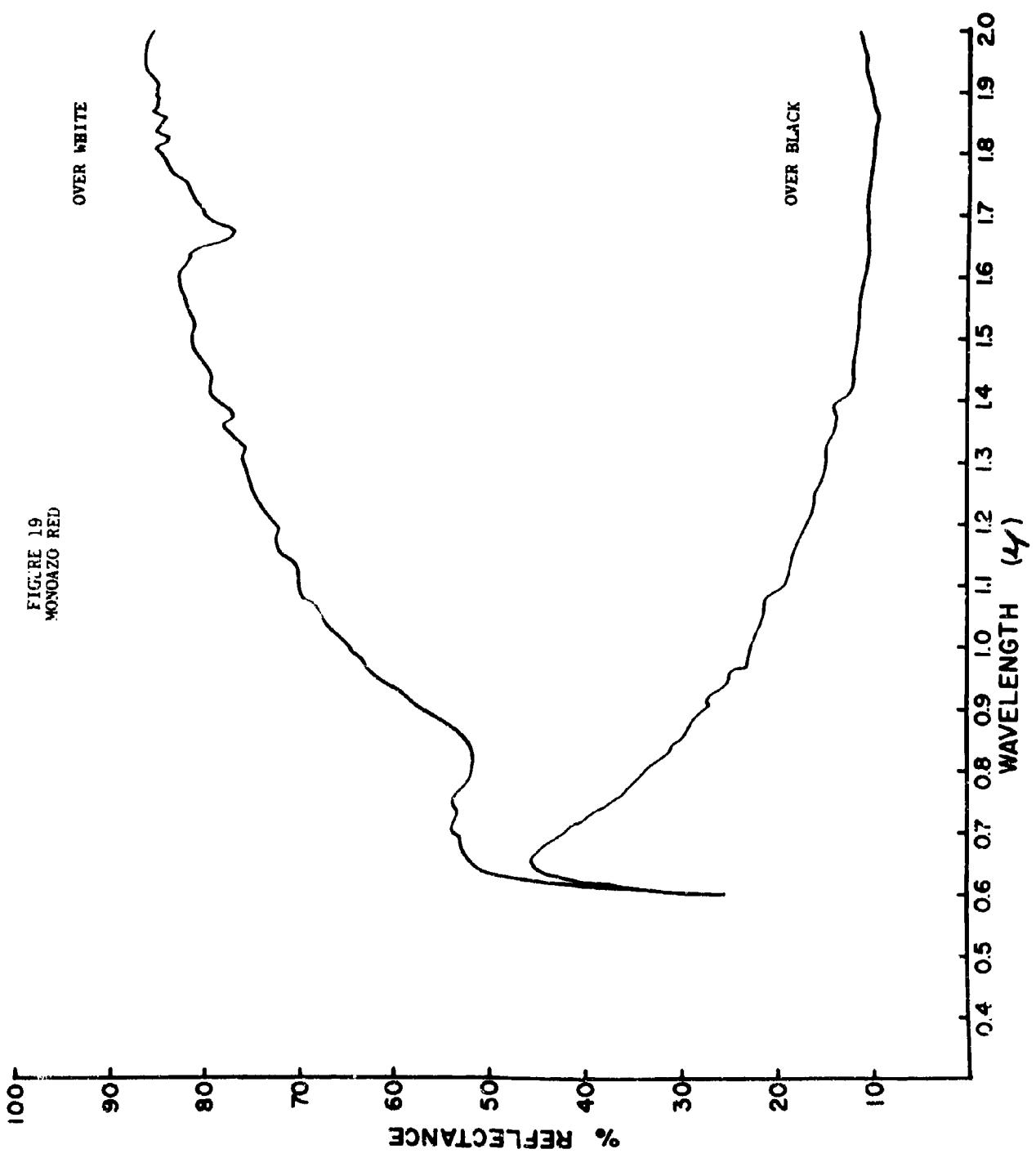
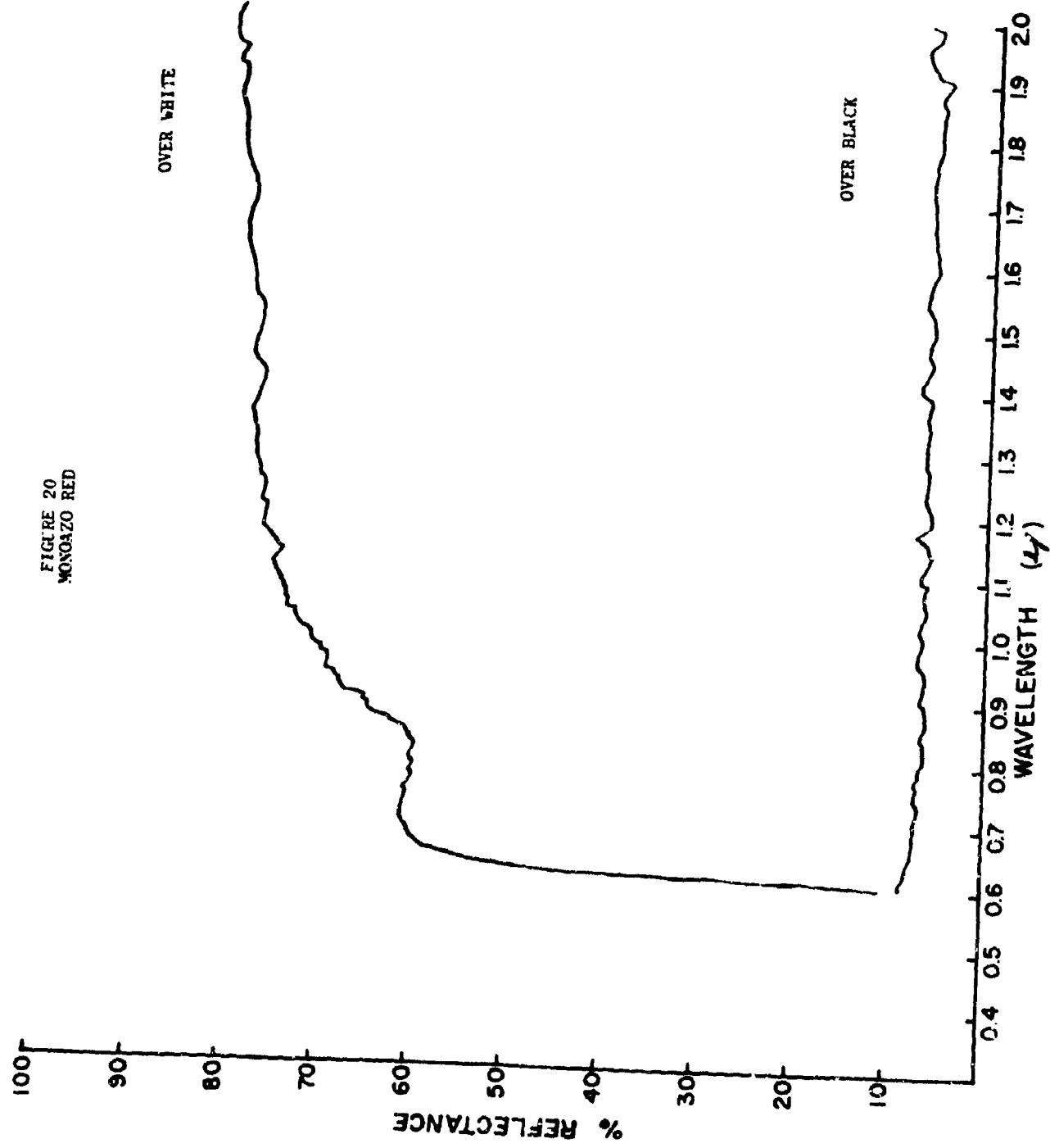


FIGURE 20  
MONOAZO RED



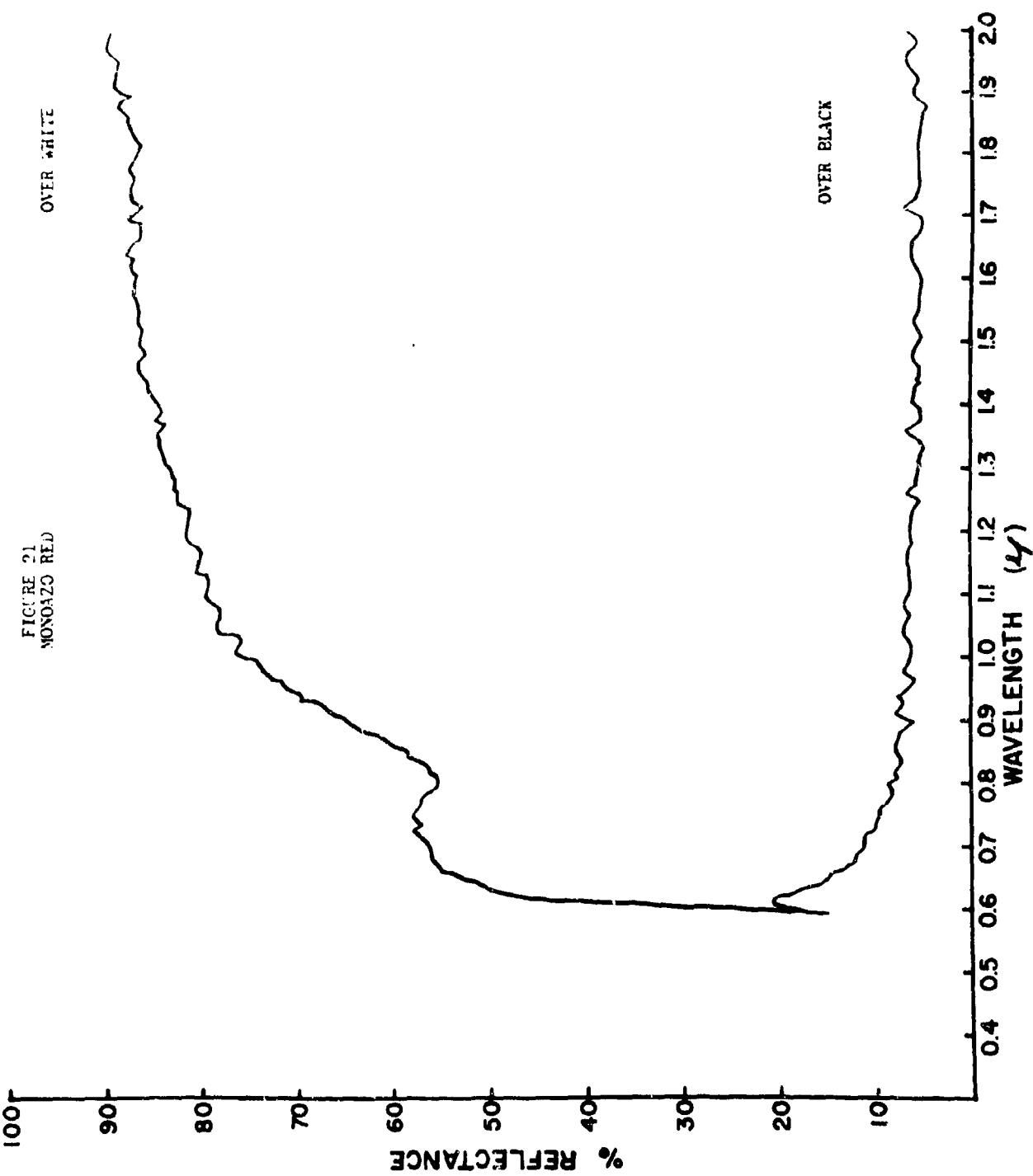


FIGURE 22  
MONOAZO RED

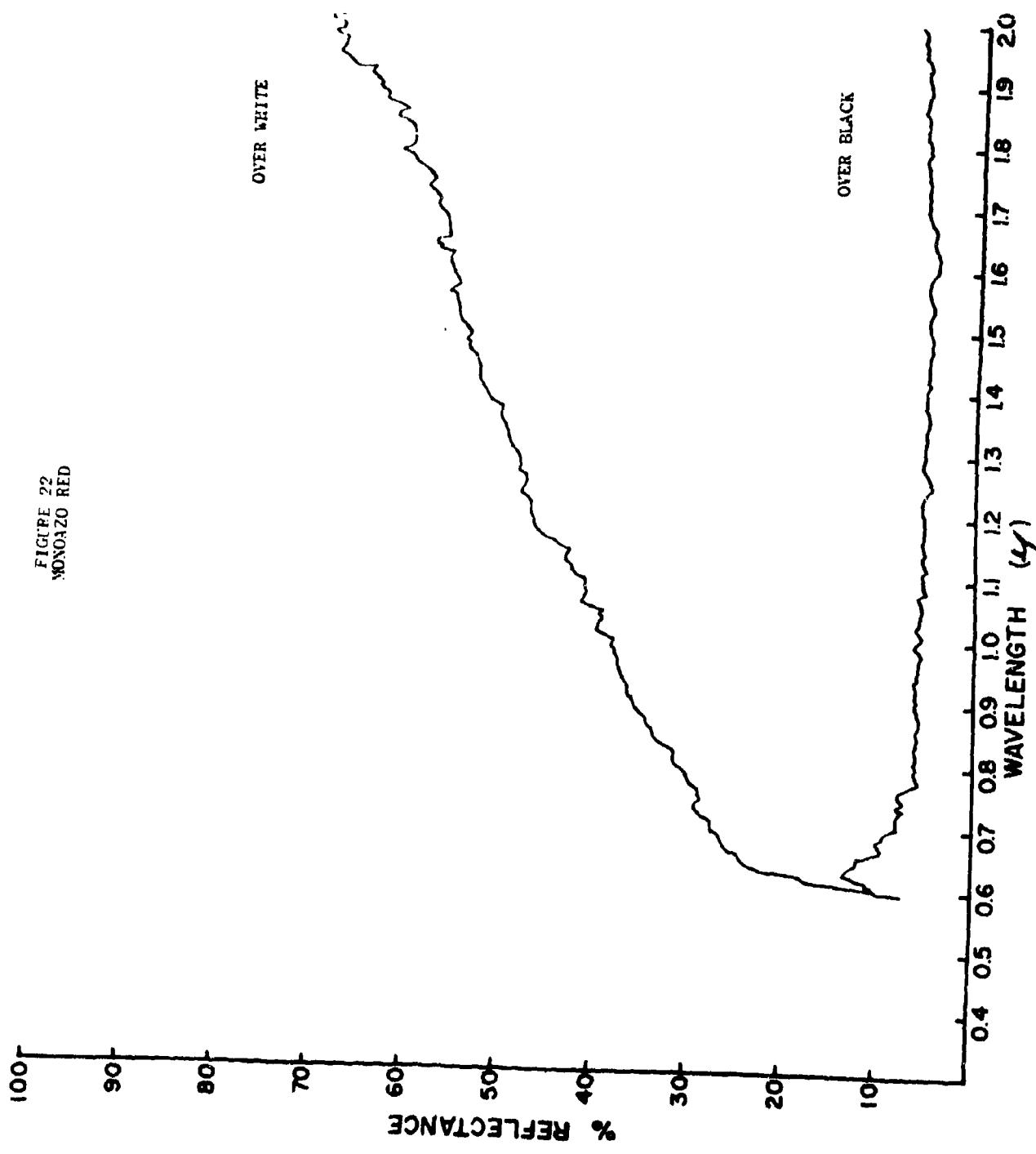


FIGURE 23  
MONOAZO RED

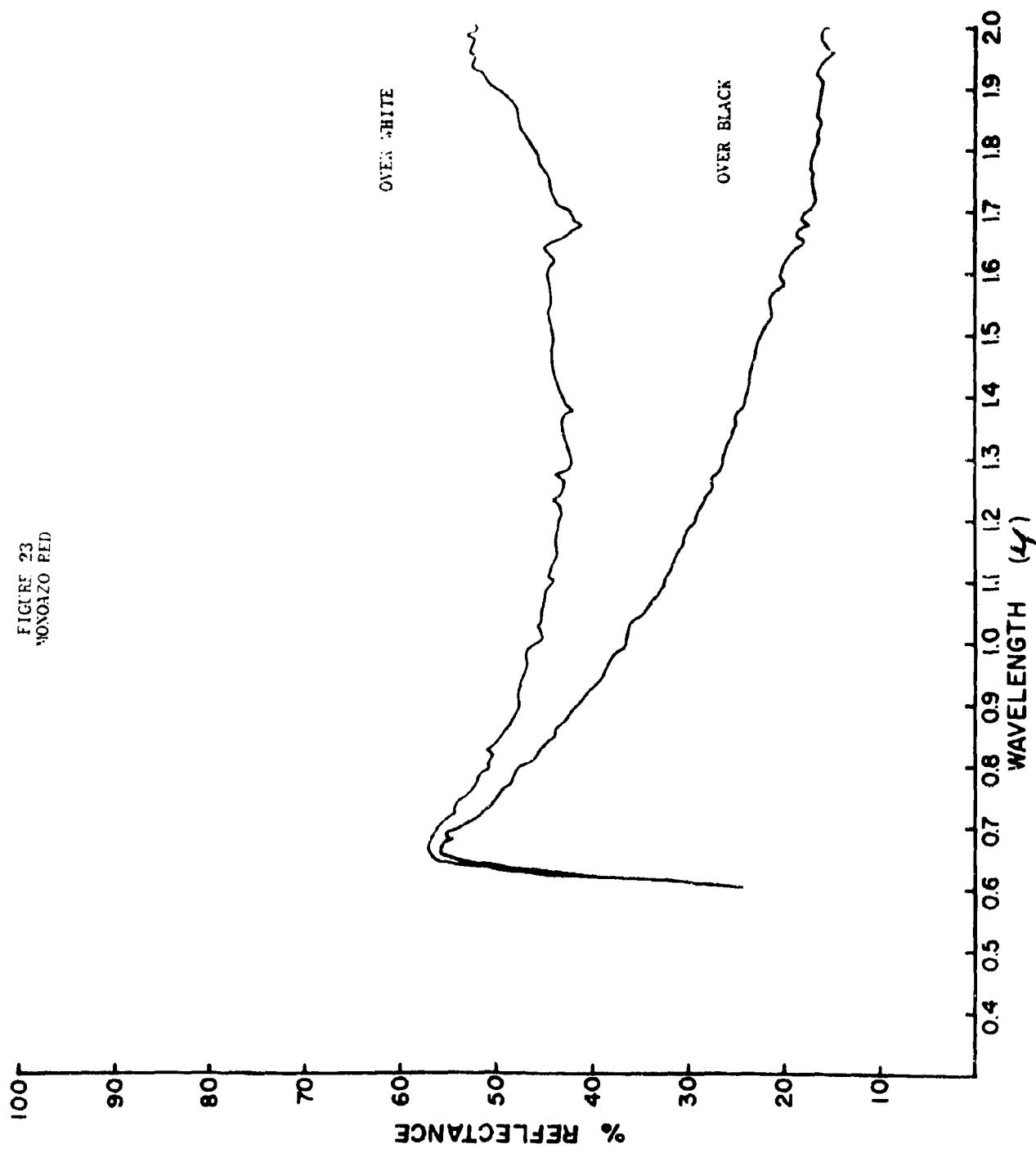


FIGURE 24  
MONGAZZ RED

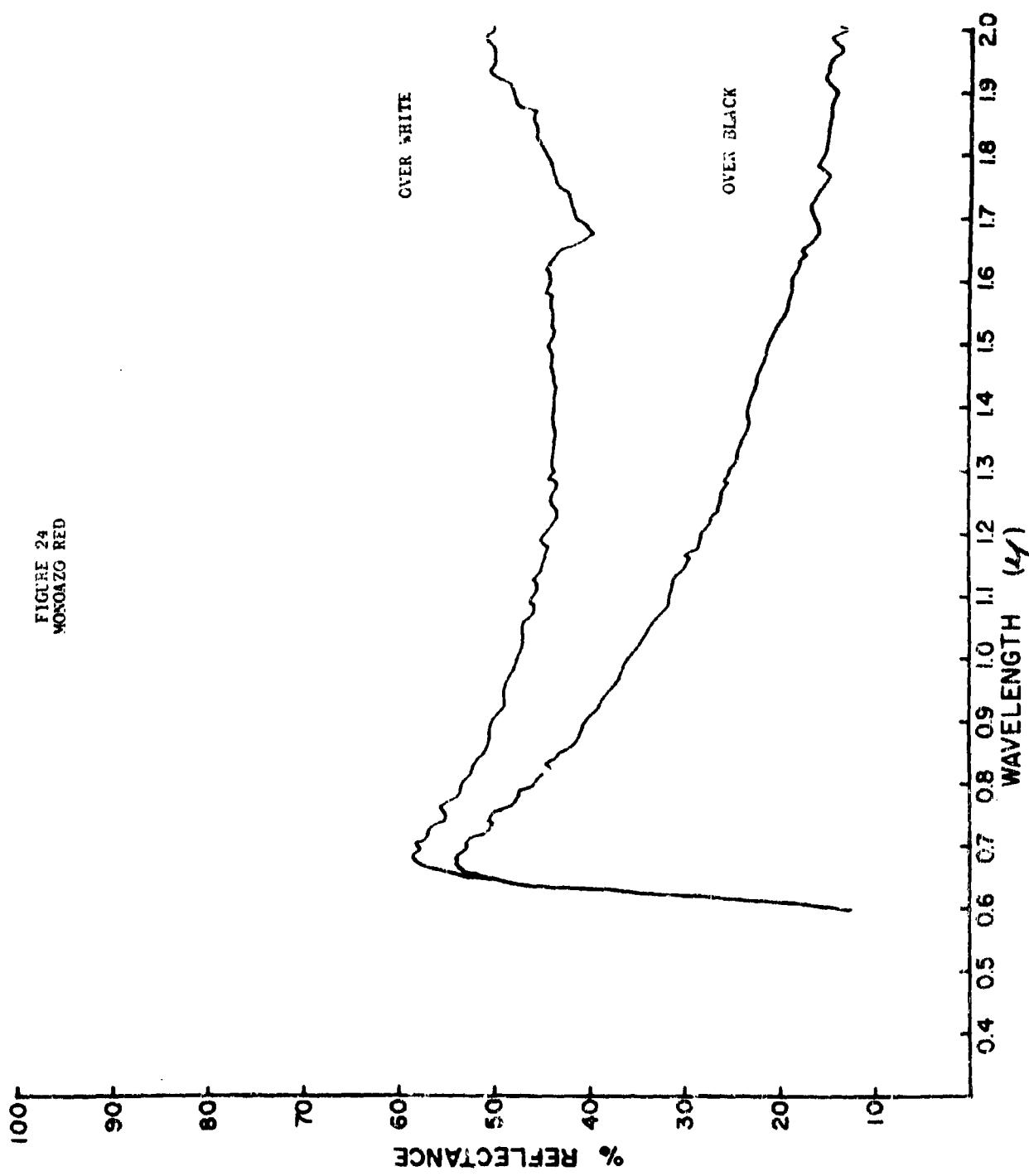
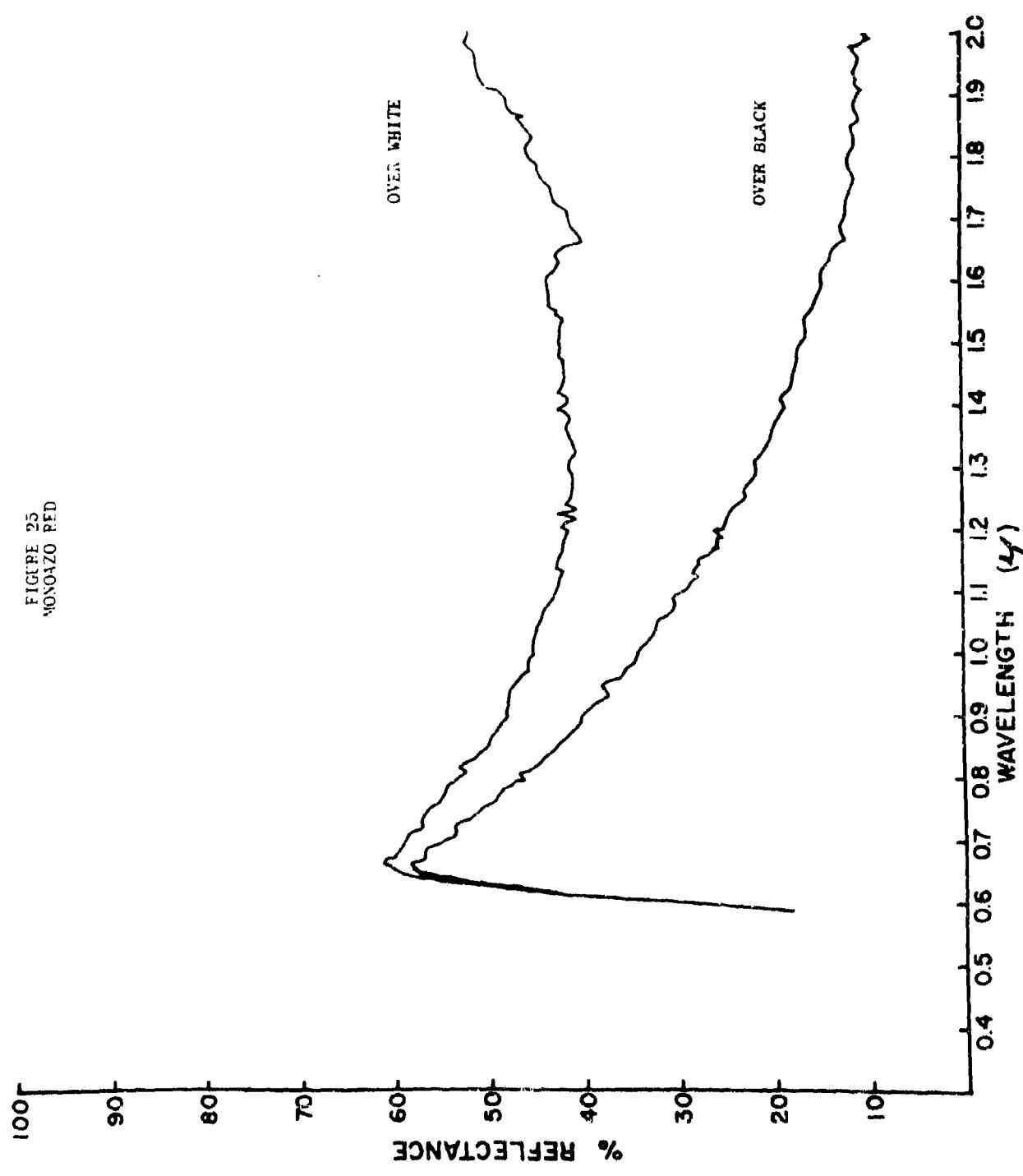


FIGURE 25  
MONOAZO RED



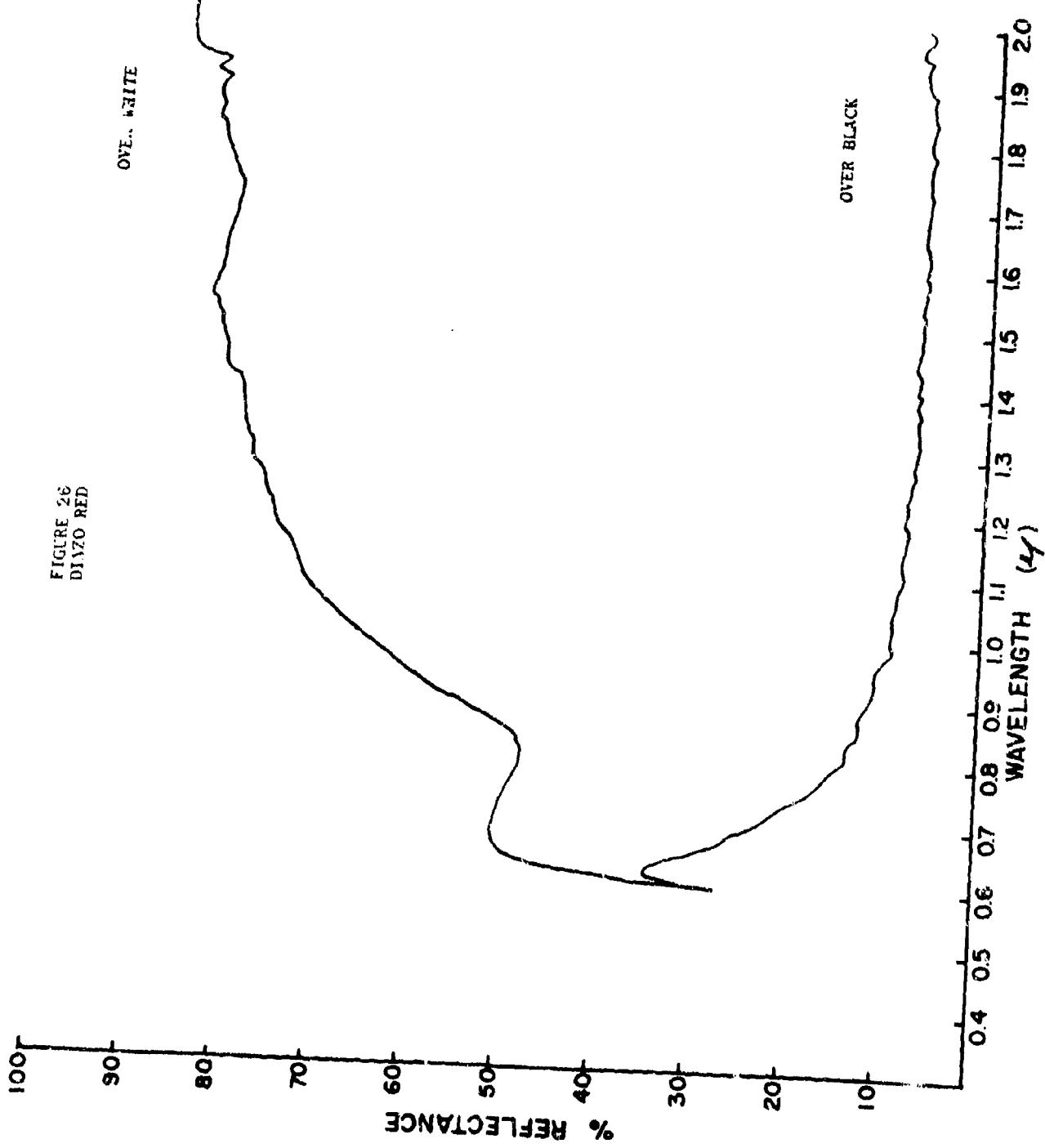


FIGURE 27  
DIAZO RED

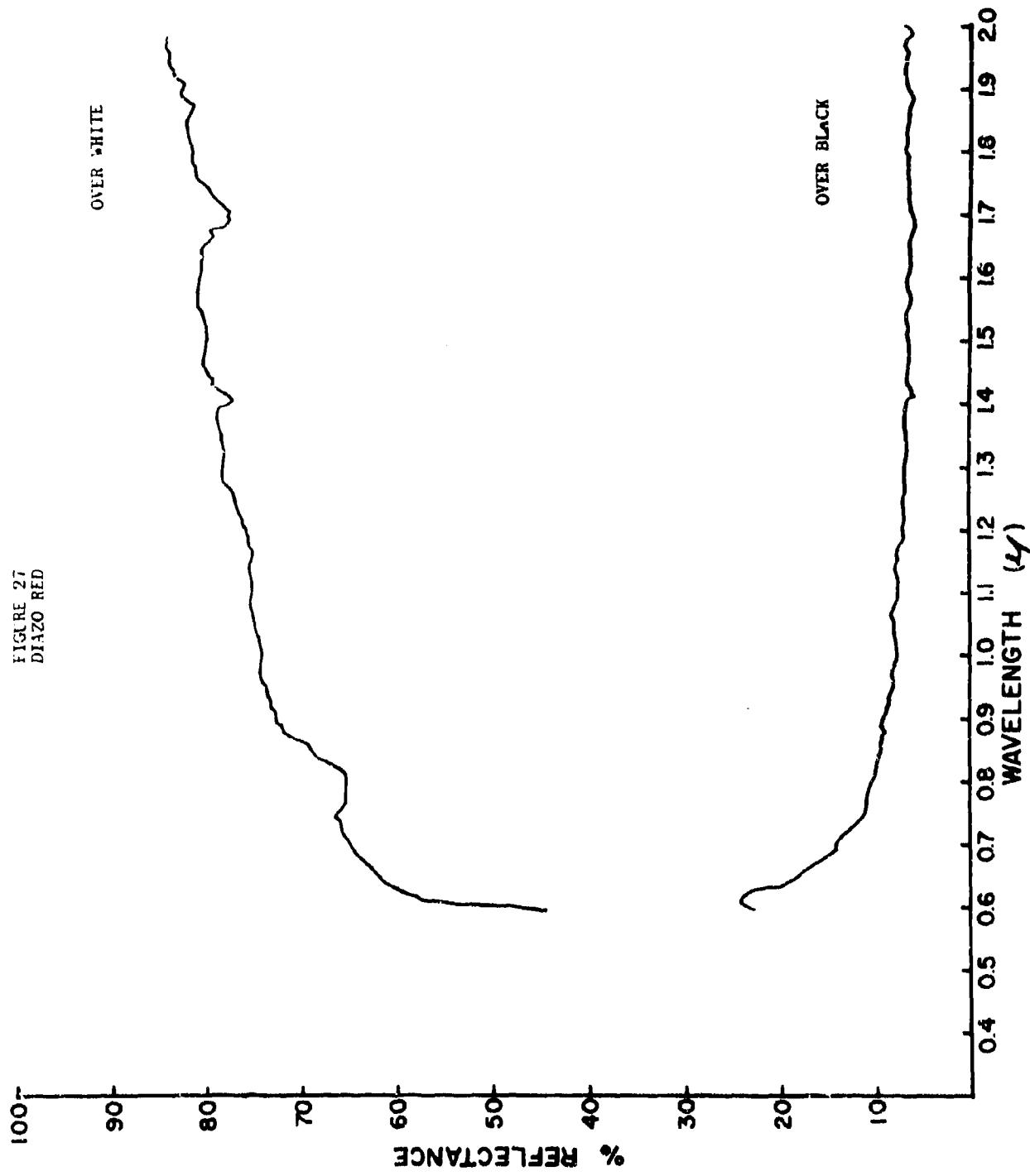


FIGURE 28  
DIAZO RFD

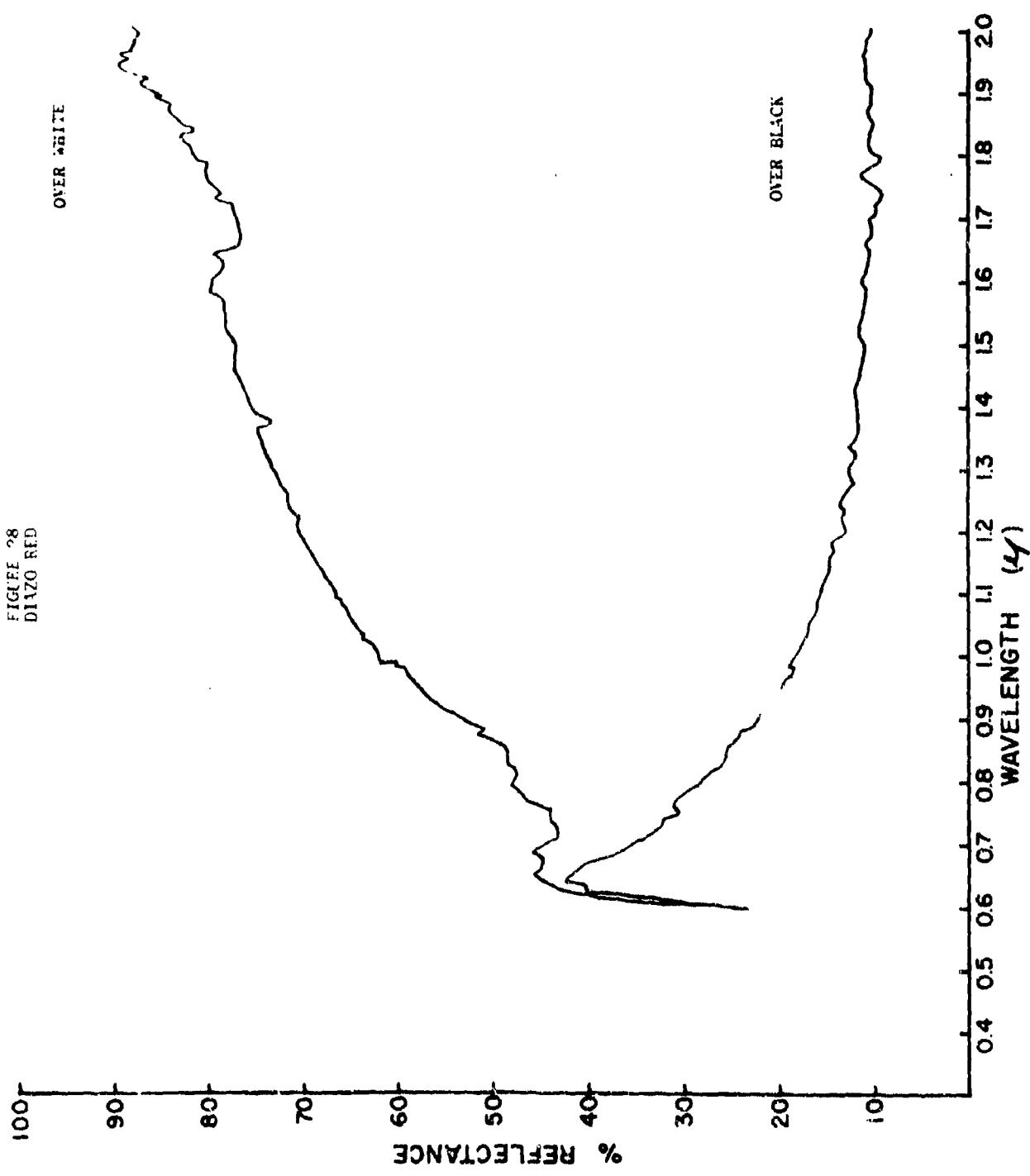


FIGURE 29  
INDIGO RED

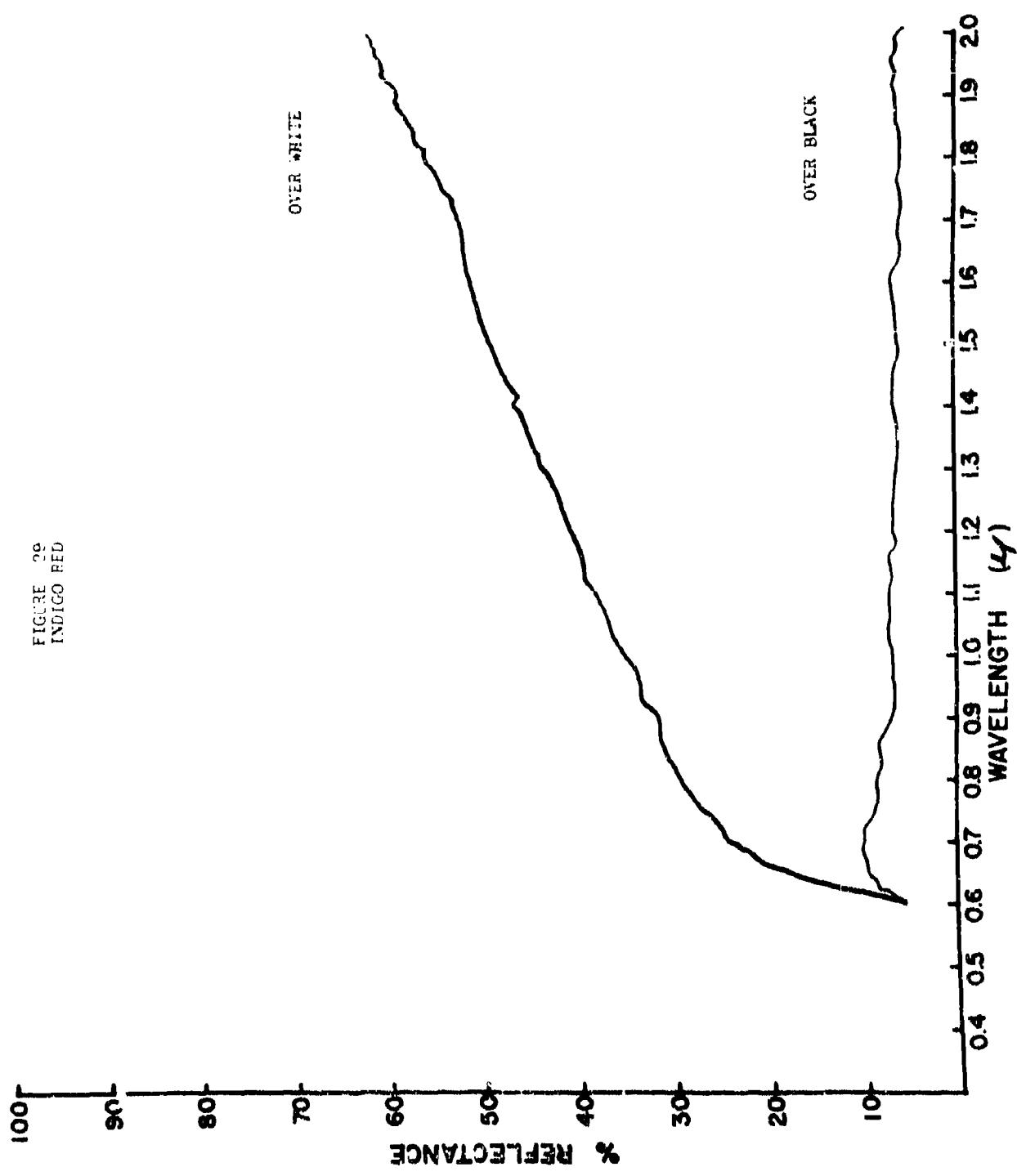


FIGURE 3<sup>a</sup>  
INDIGO GRP

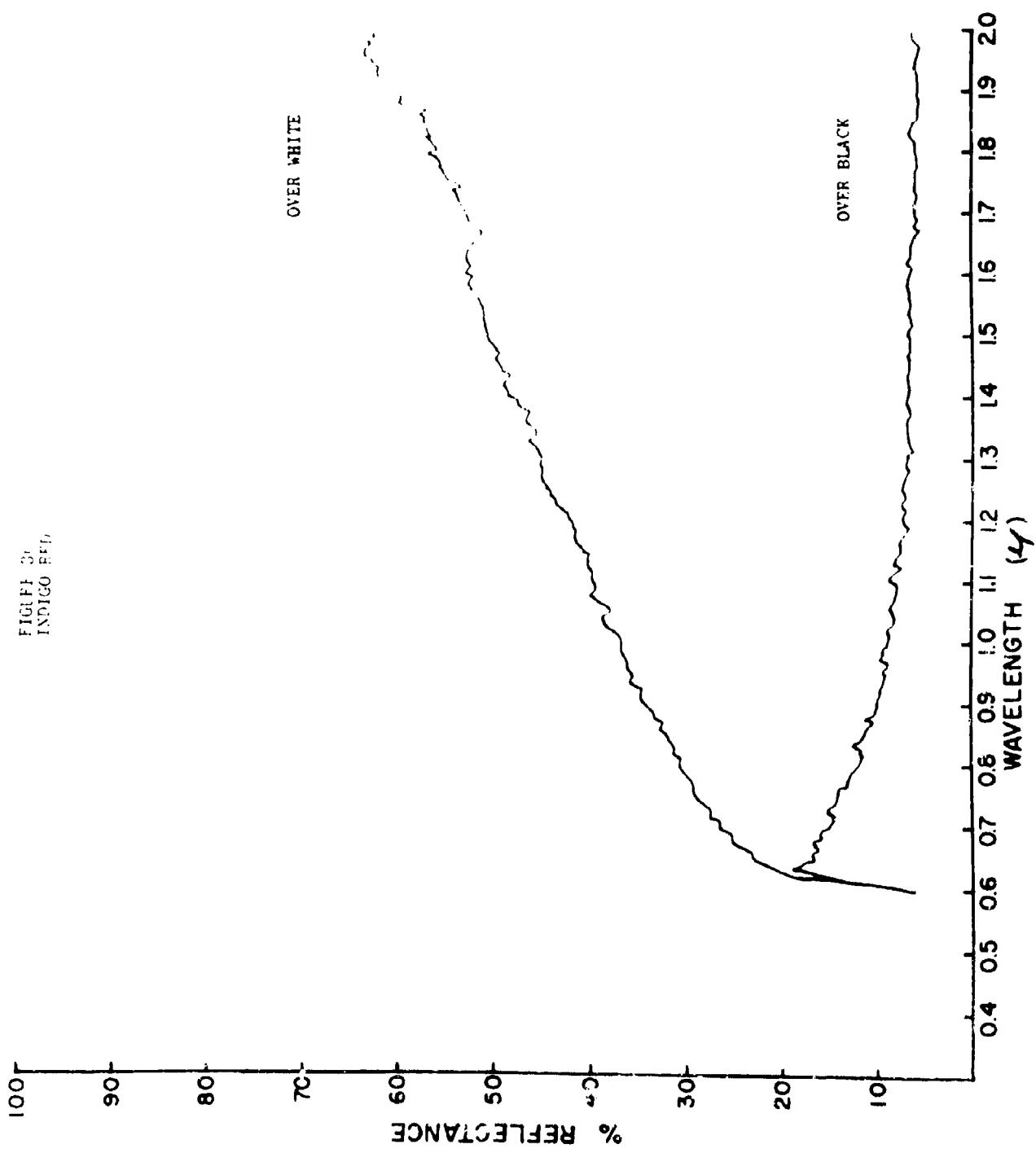


FIGURE 31  
ISONDOLINE RED

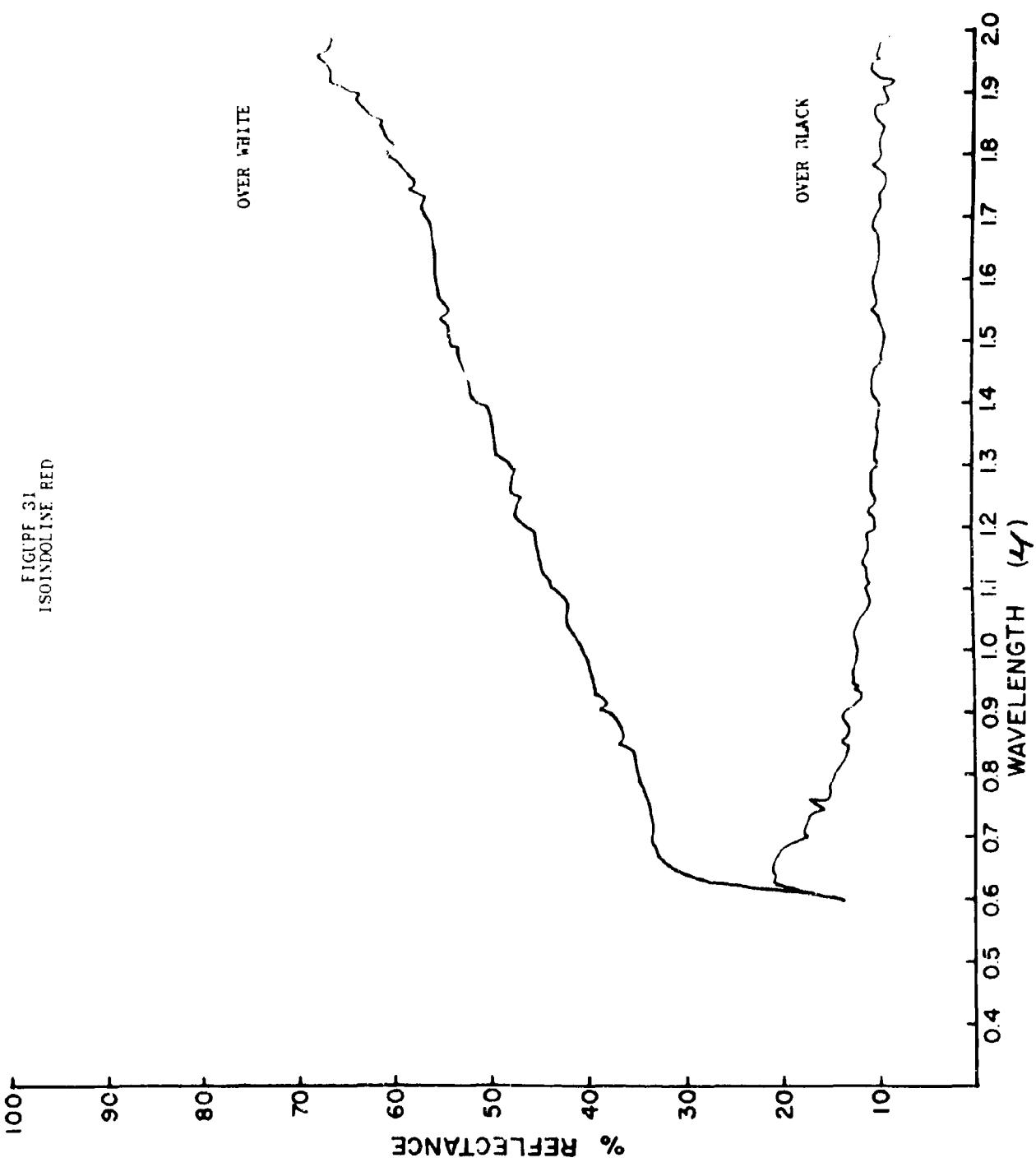
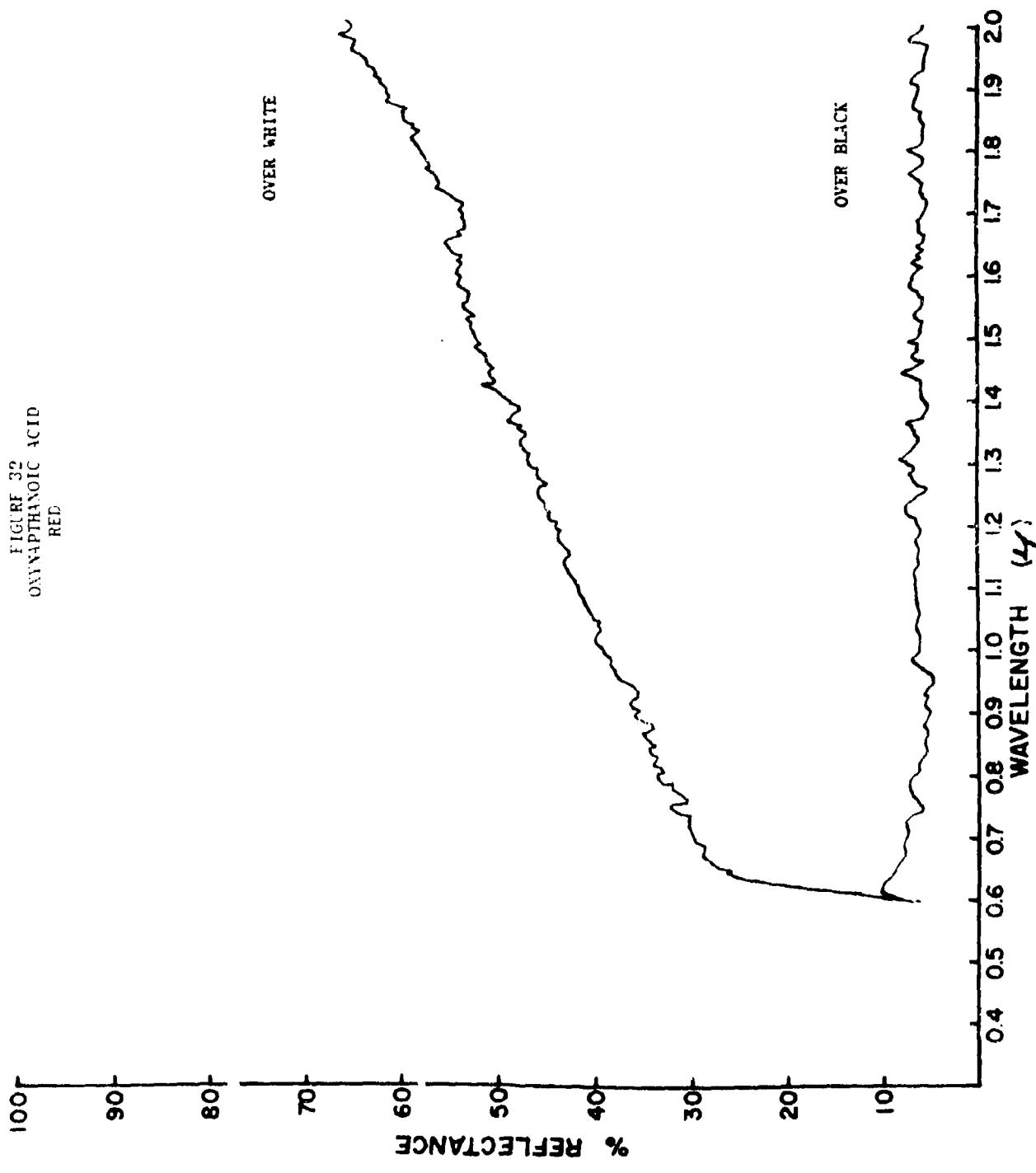


FIGURE 32  
OXYPHTHALIC ACID  
RED



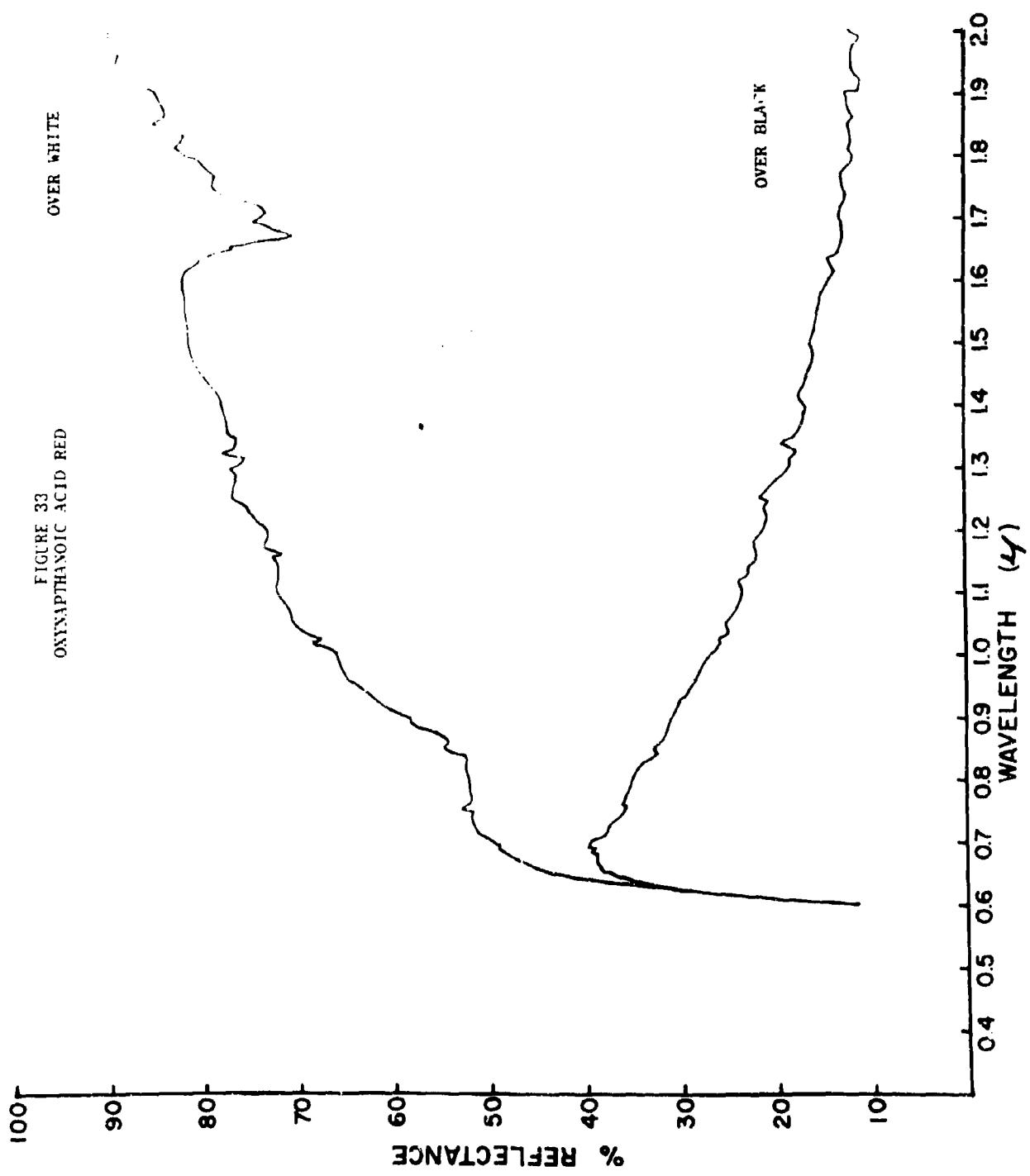


FIGURE 34  
PFR WLFNE PFD

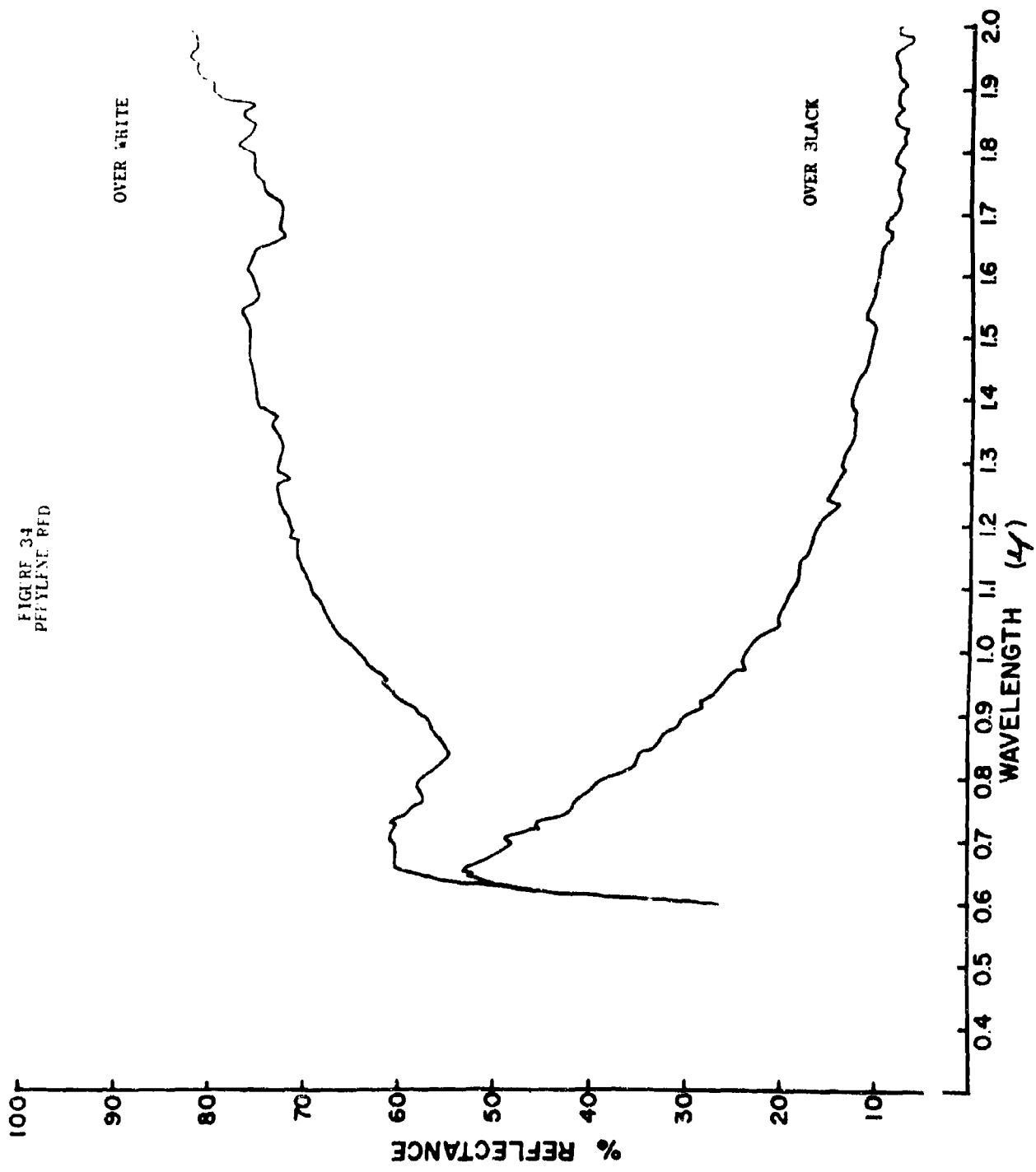


FIGURE 35  
PERYLONE RED

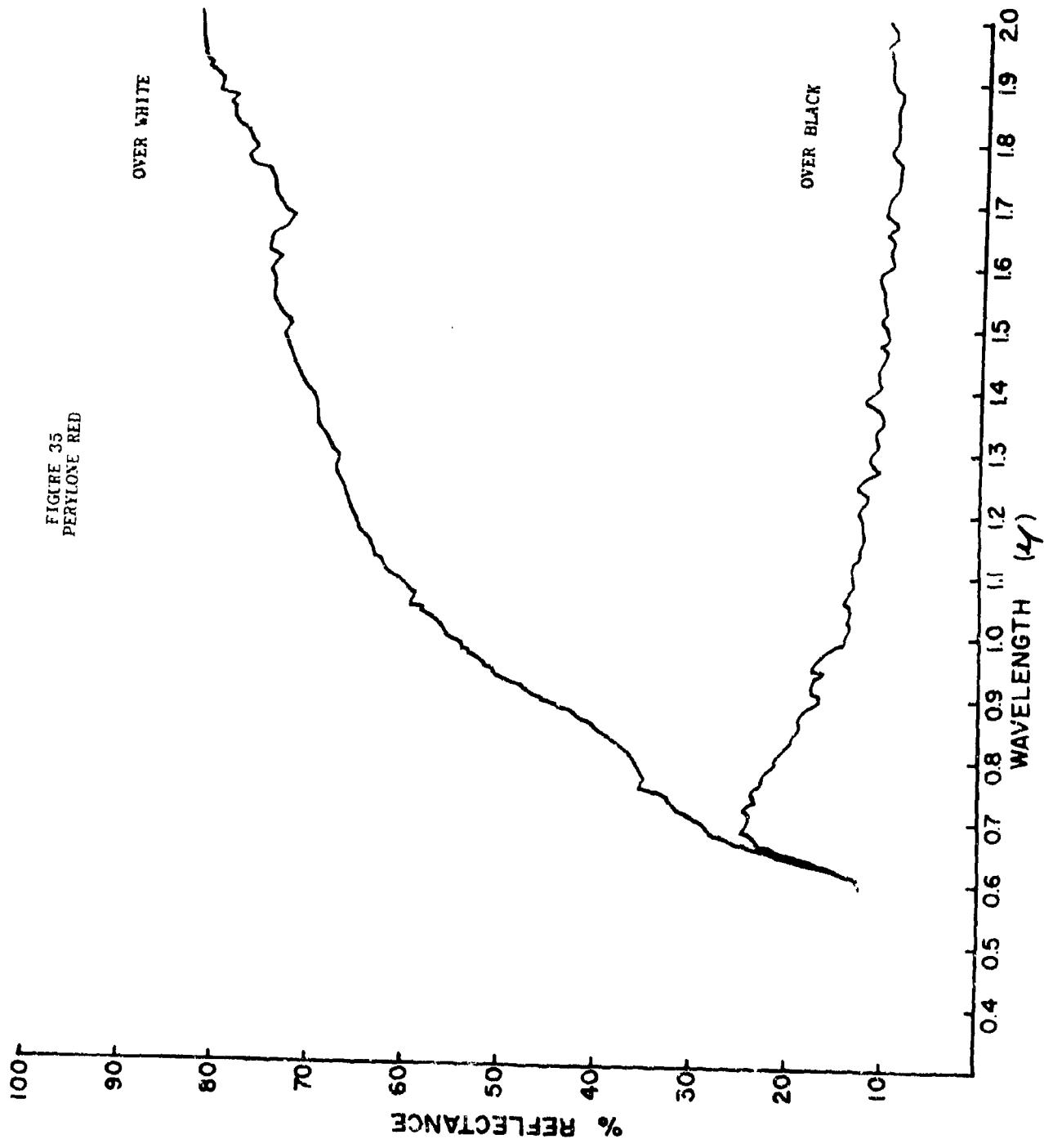


FIGURE 7  
PYRAZOLONE RFI

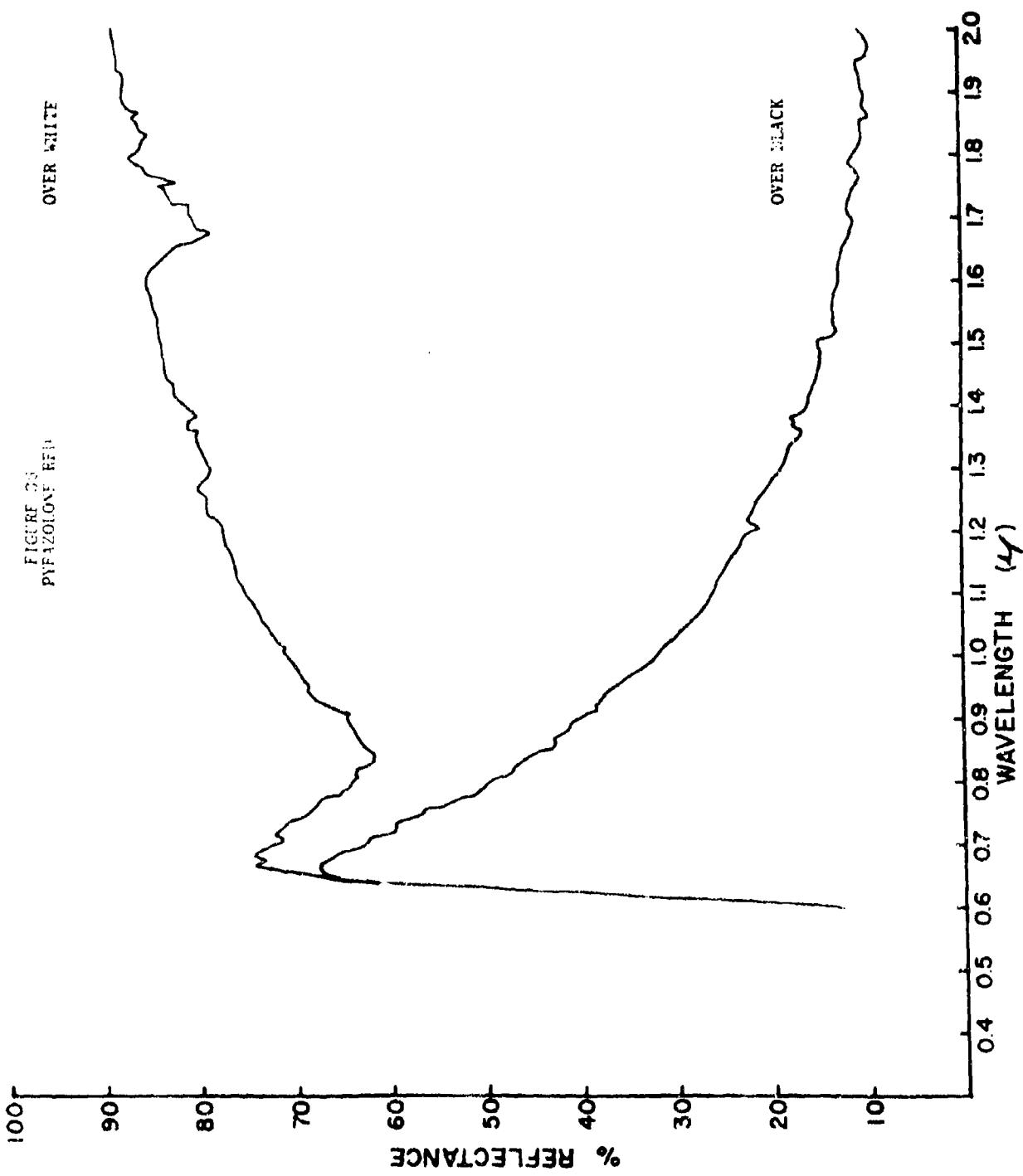


FIGURE 37  
QUINACRIDONE RED

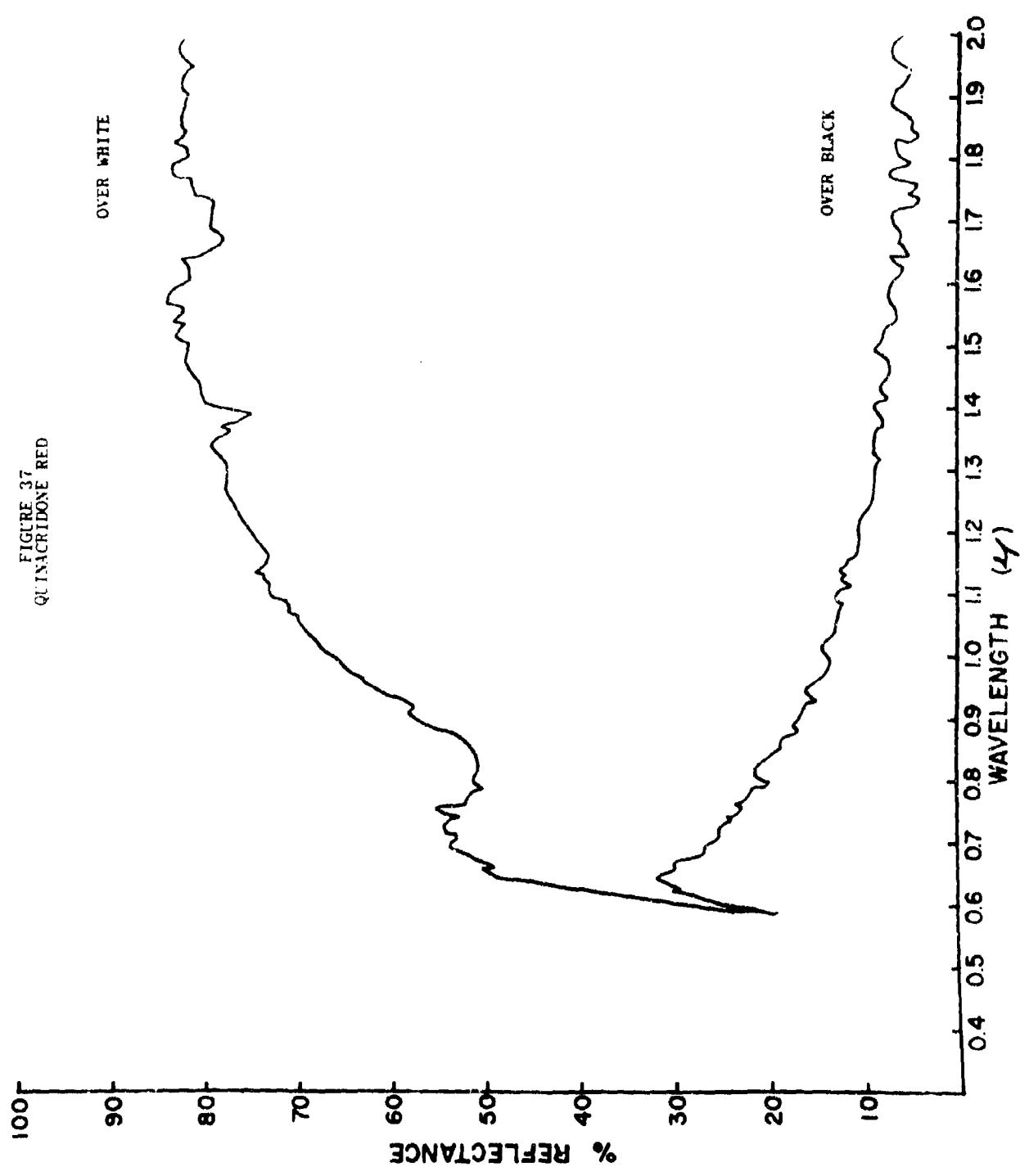


FIGURE 38  
QUINACRIDONE RED

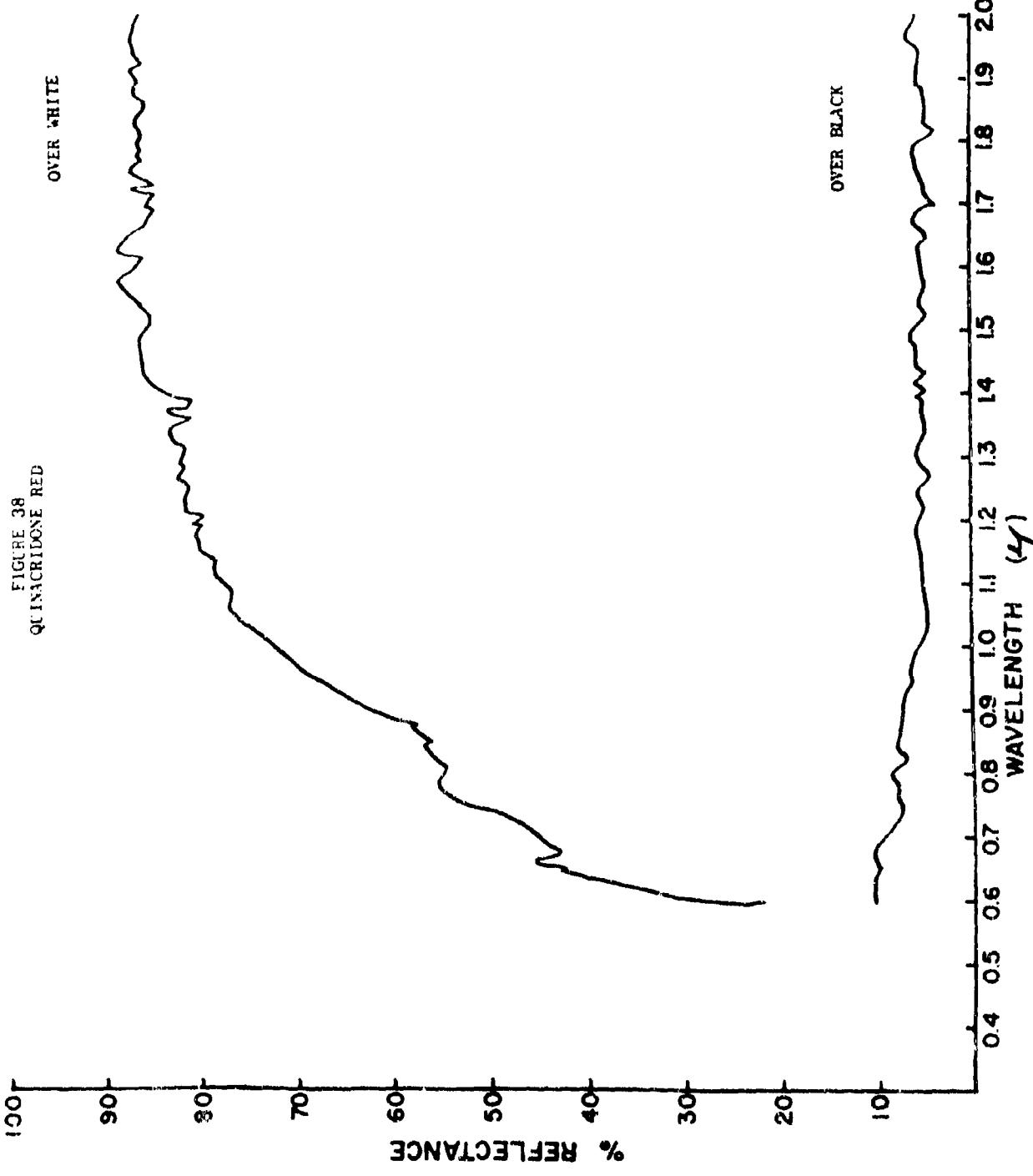


FIGURE 39  
QUINACRIDONE RED

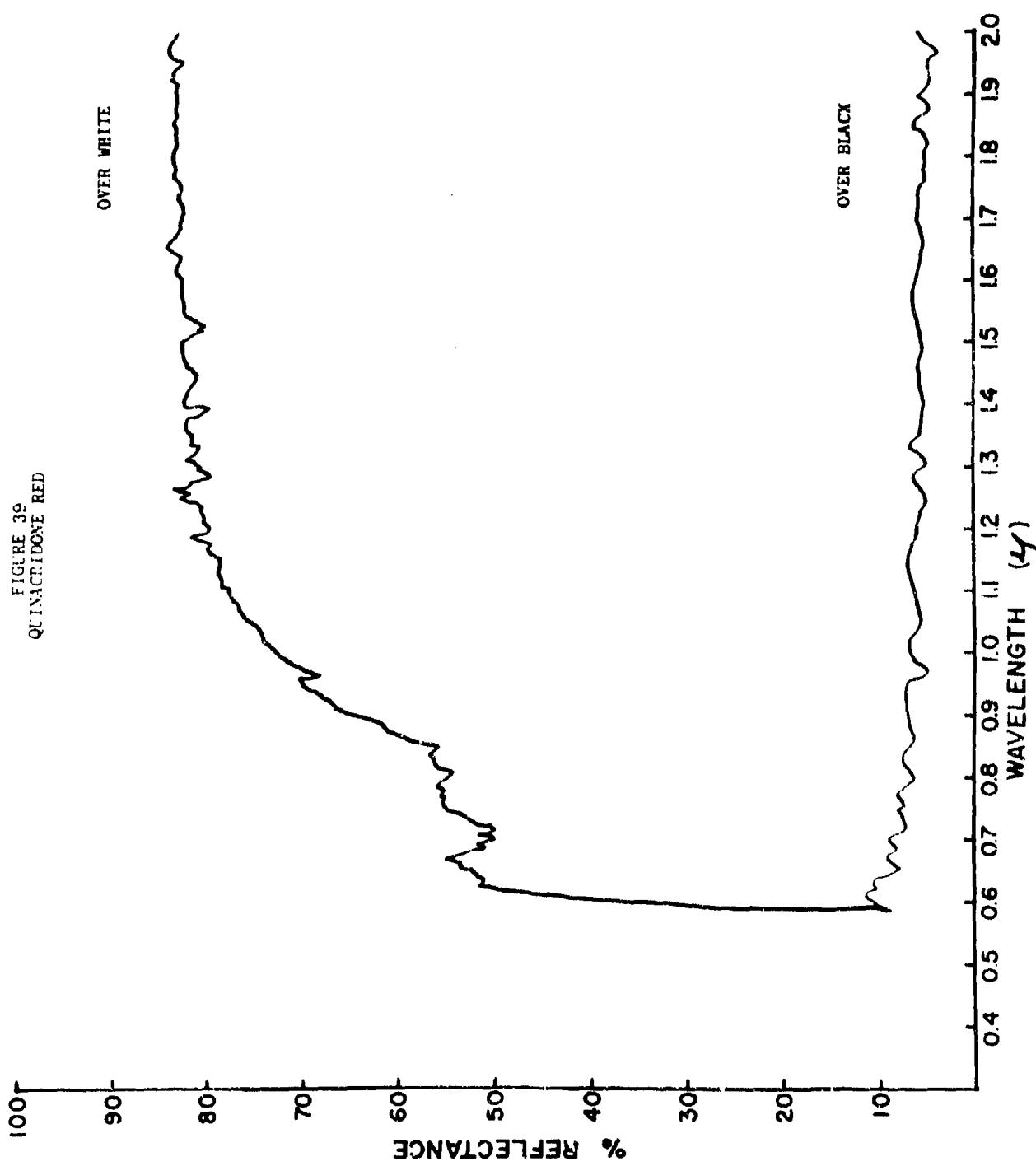
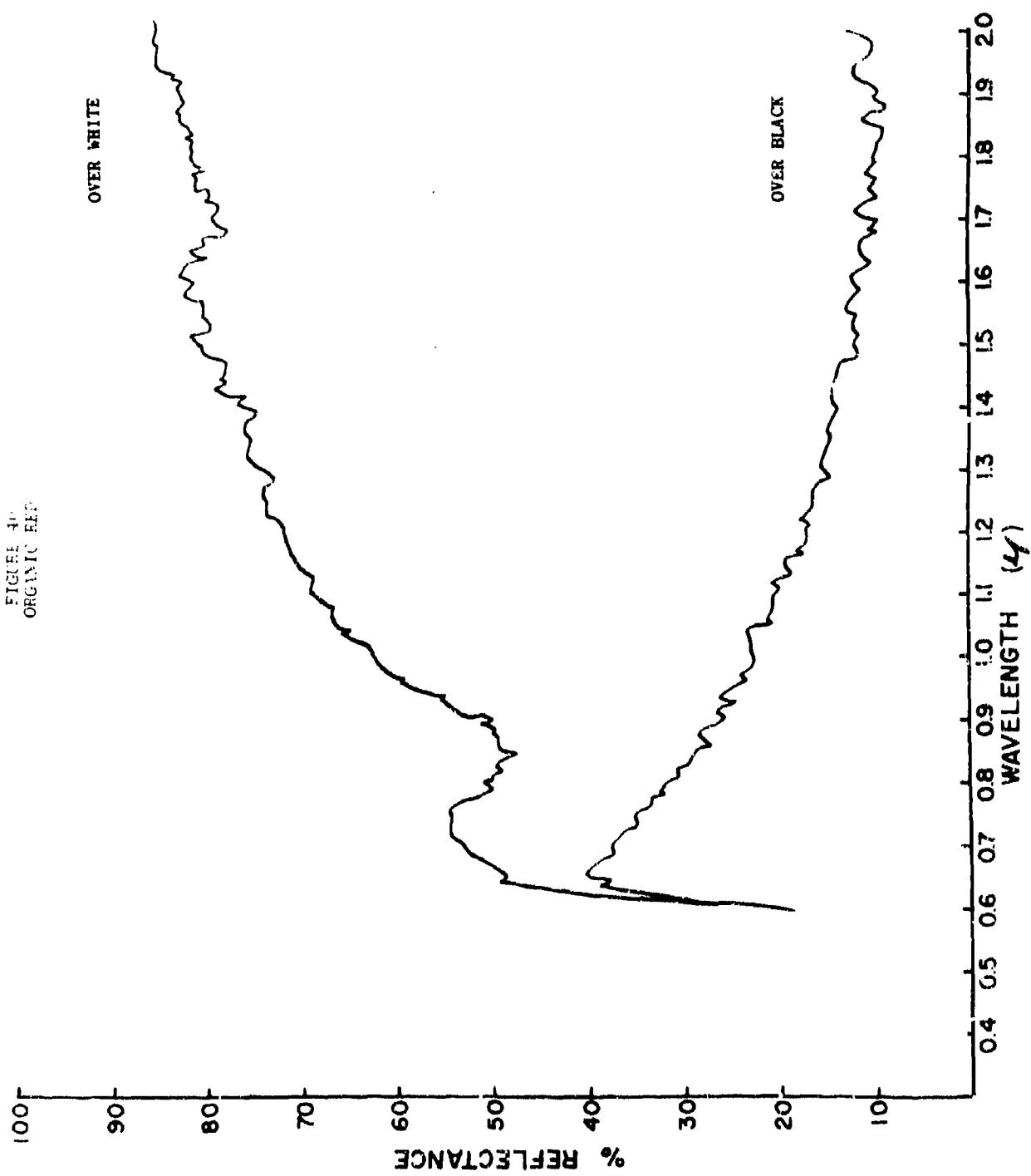


FIGURE 4  
ORGANIC FIBER



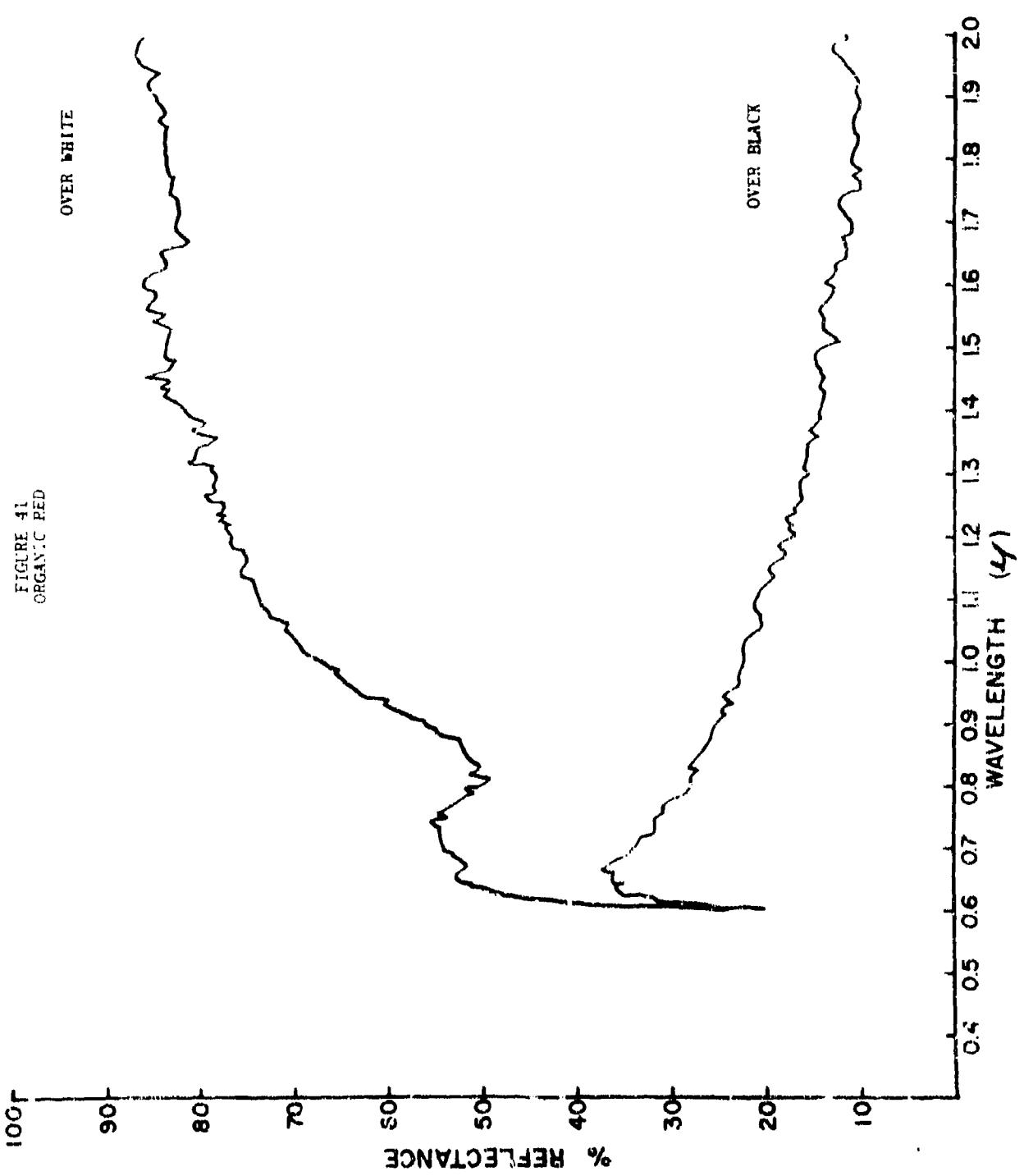
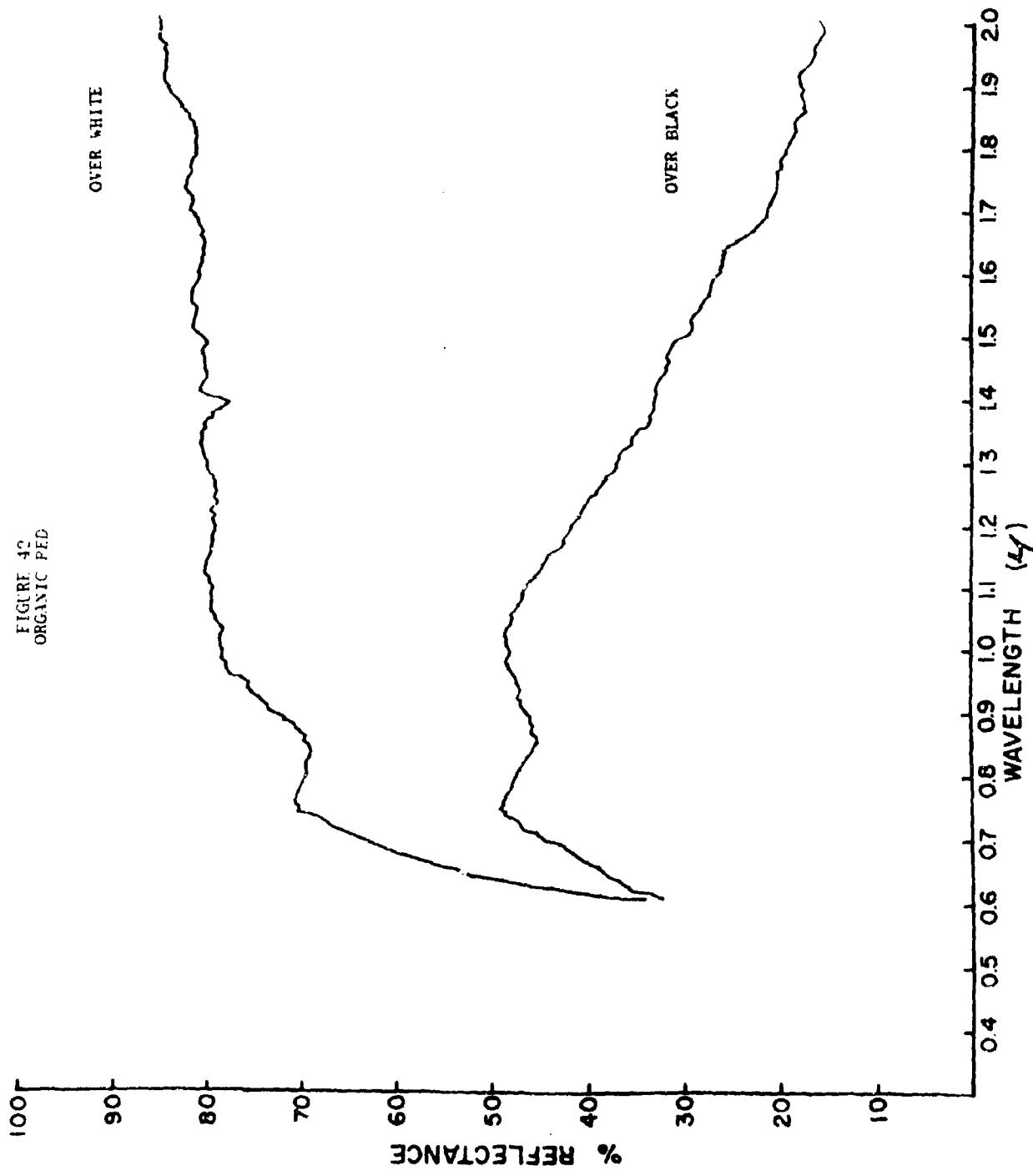


FIGURE 42  
ORGANIC PFD



LIGHT 1  
MONOCHROMATOR

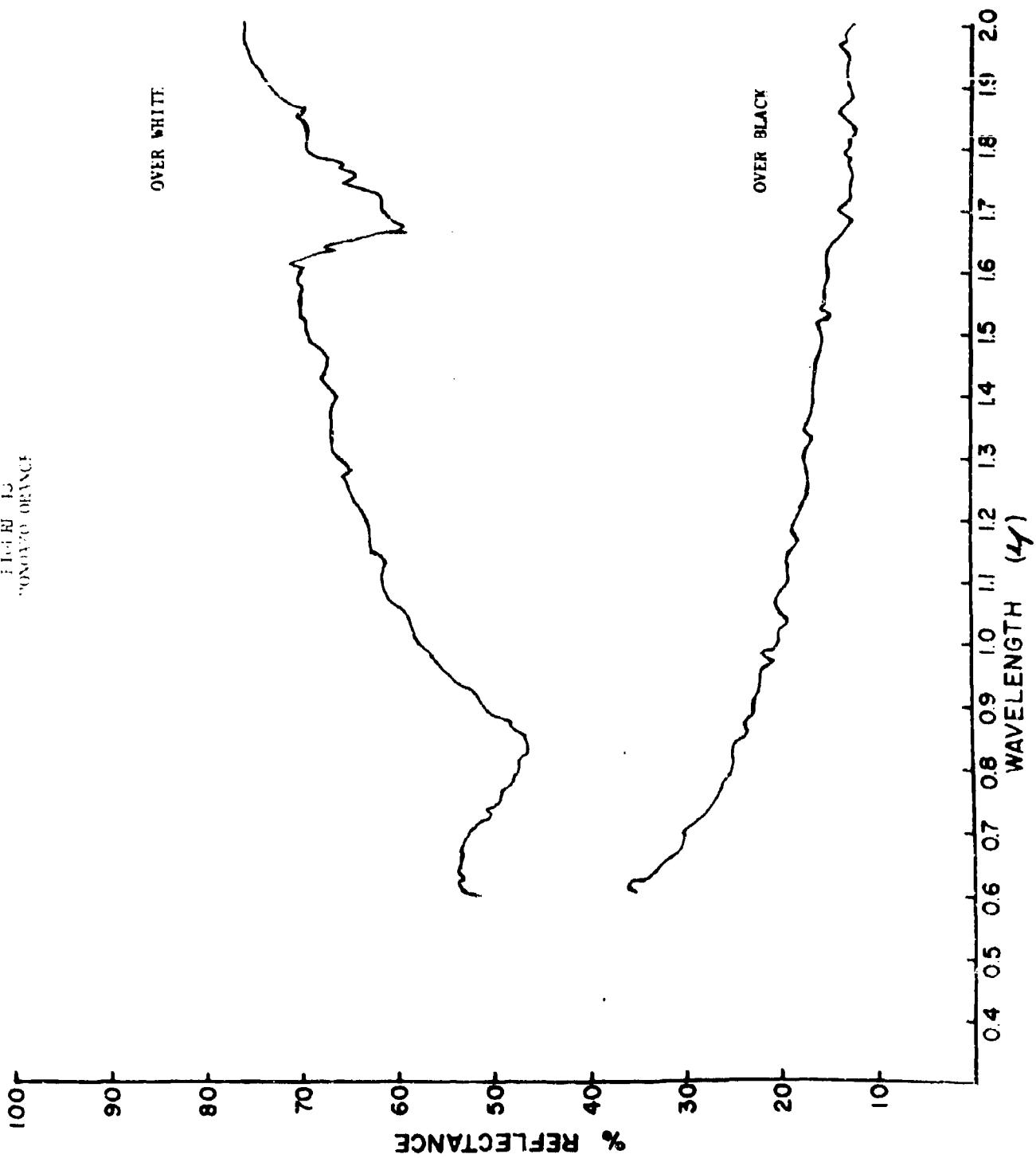


FIGURE 44  
DIAZO ORANGE

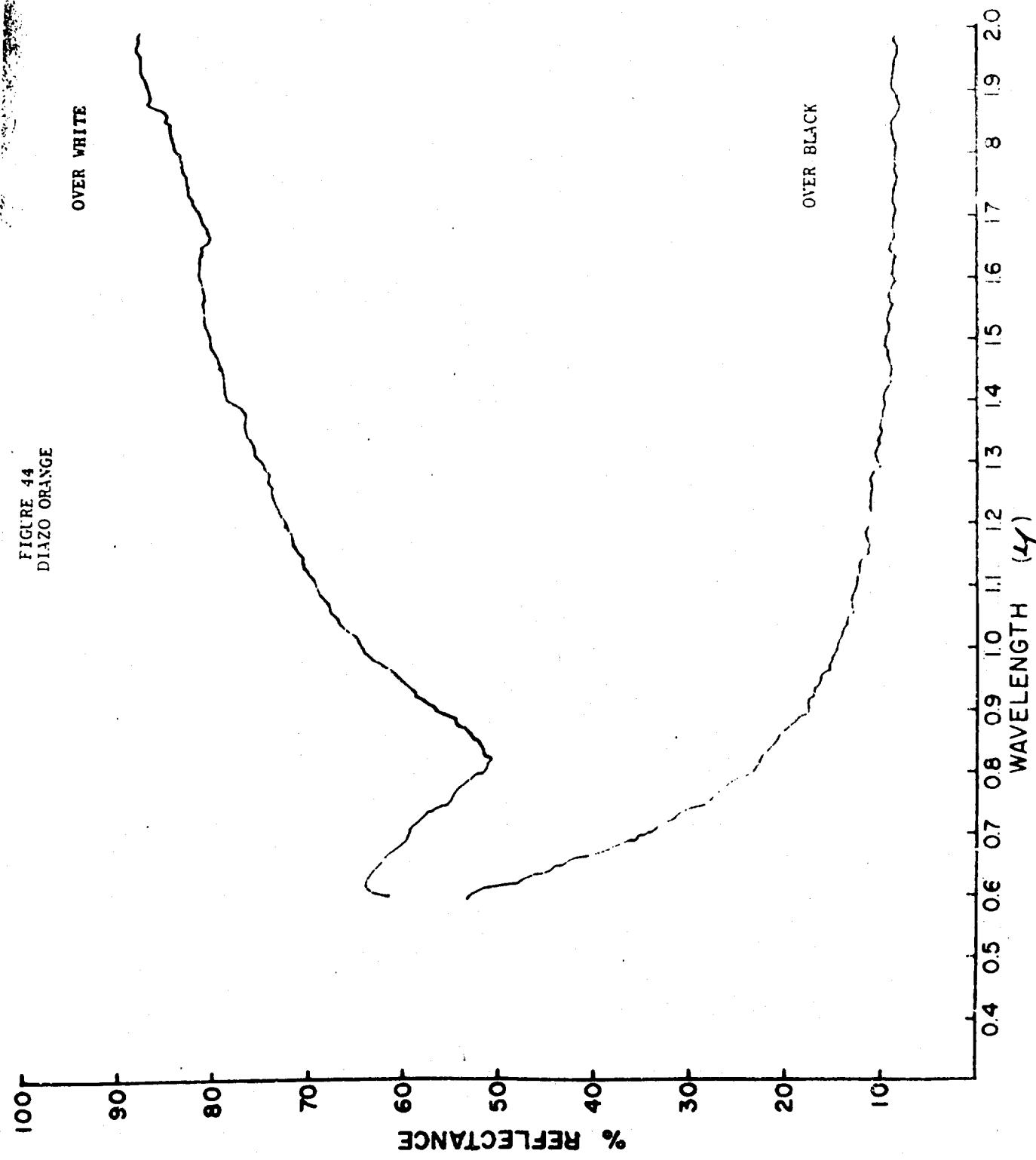


FIGURE 45  
ISOPINDOLINE ORANGE

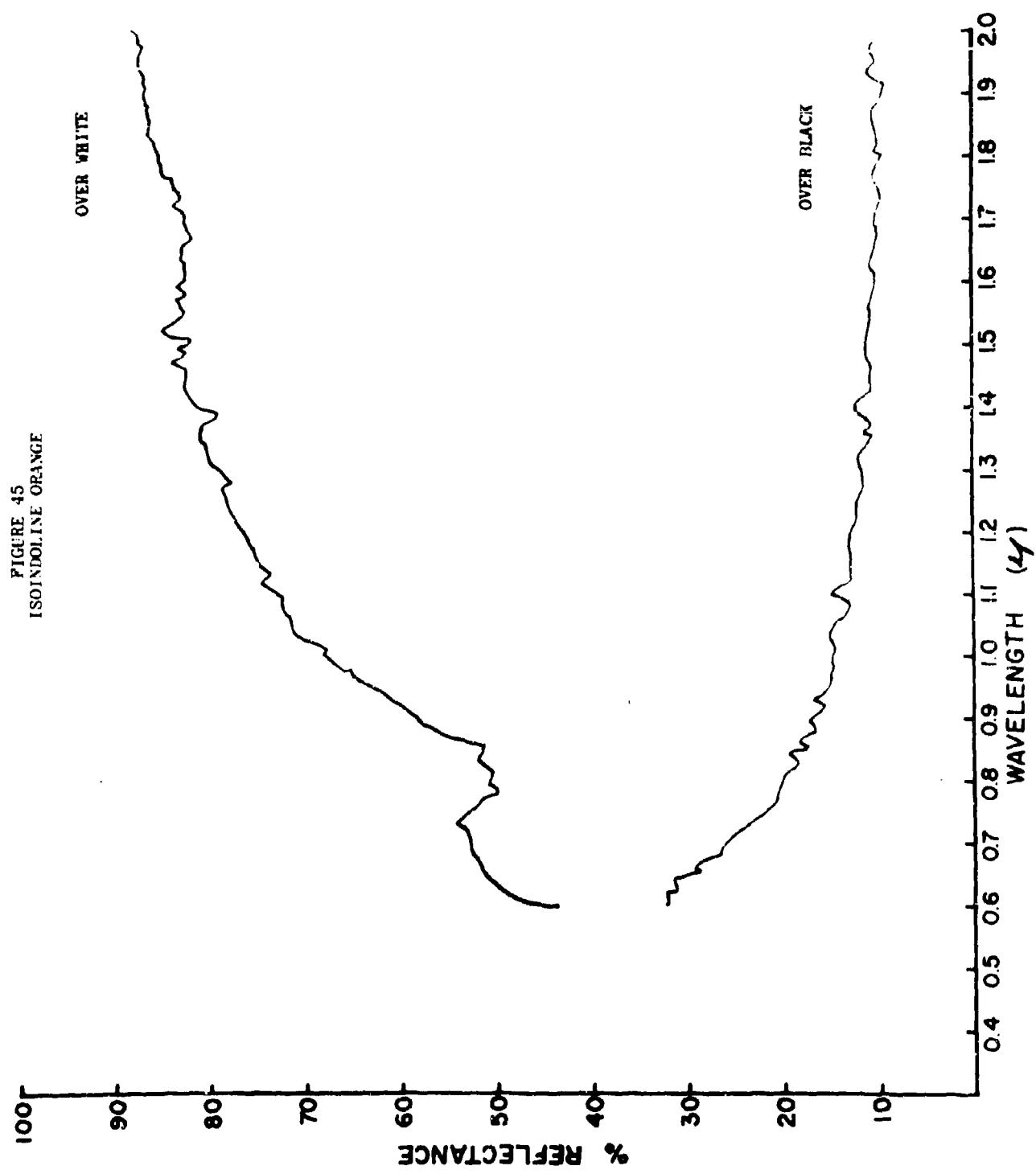


FIGURE 16  
NAPHTHALENE TETRA-  
CARBOXYLIC ACID ORANGE

OVER WHITE

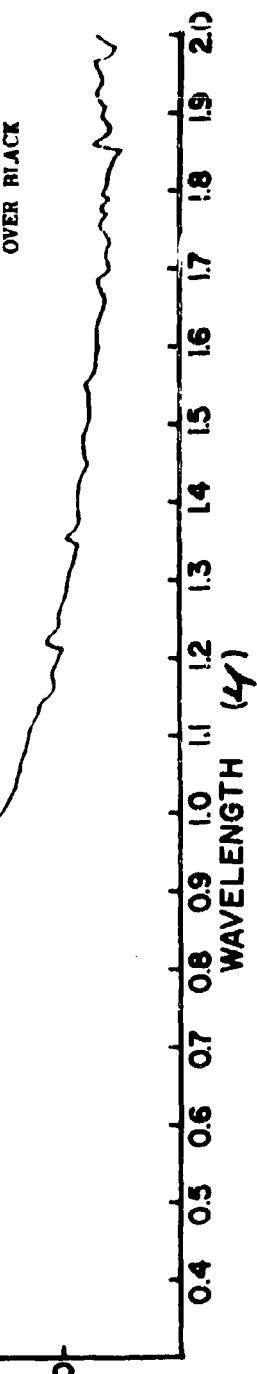


FIGURE 47  
NITRO-ORANGE

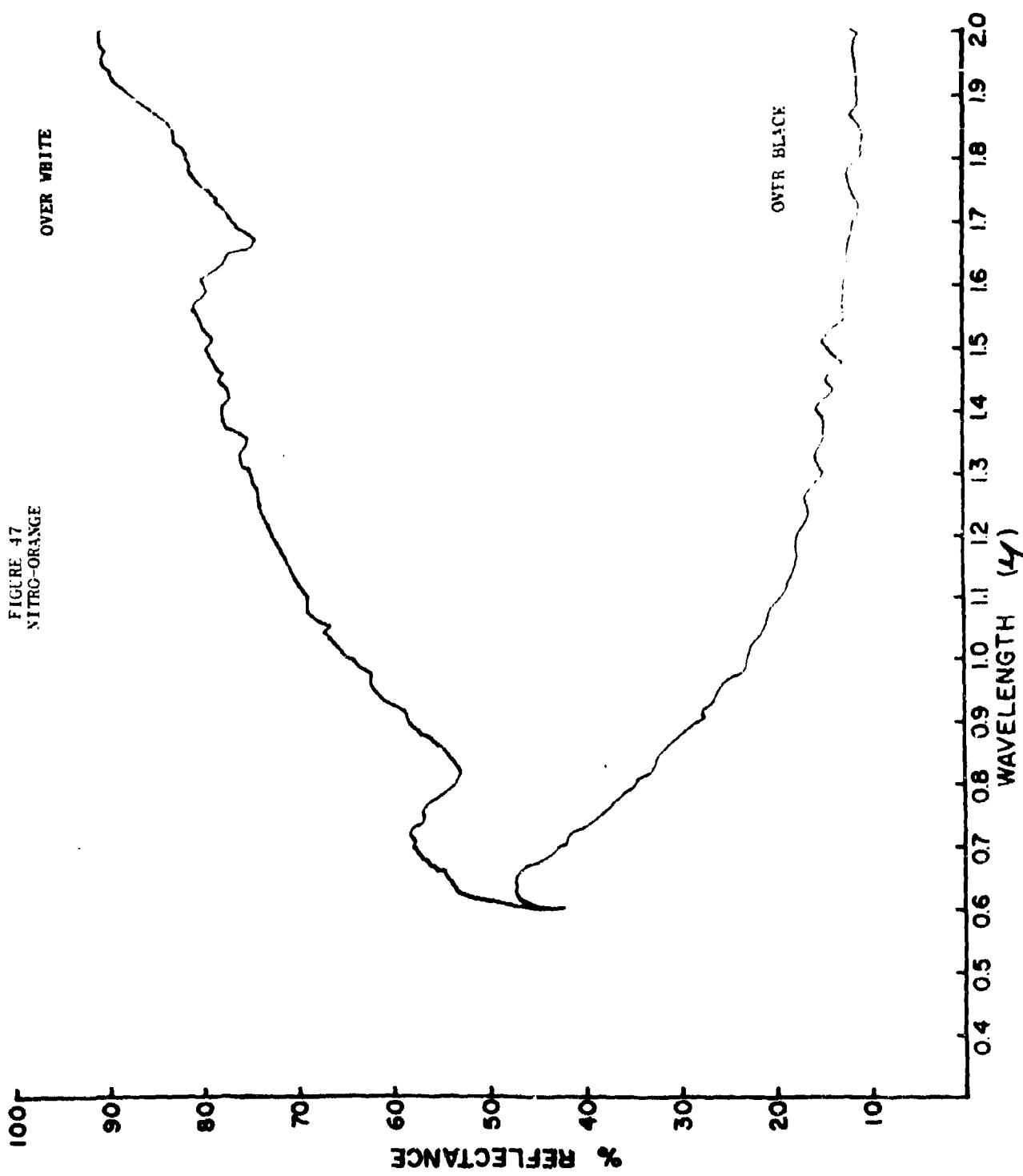
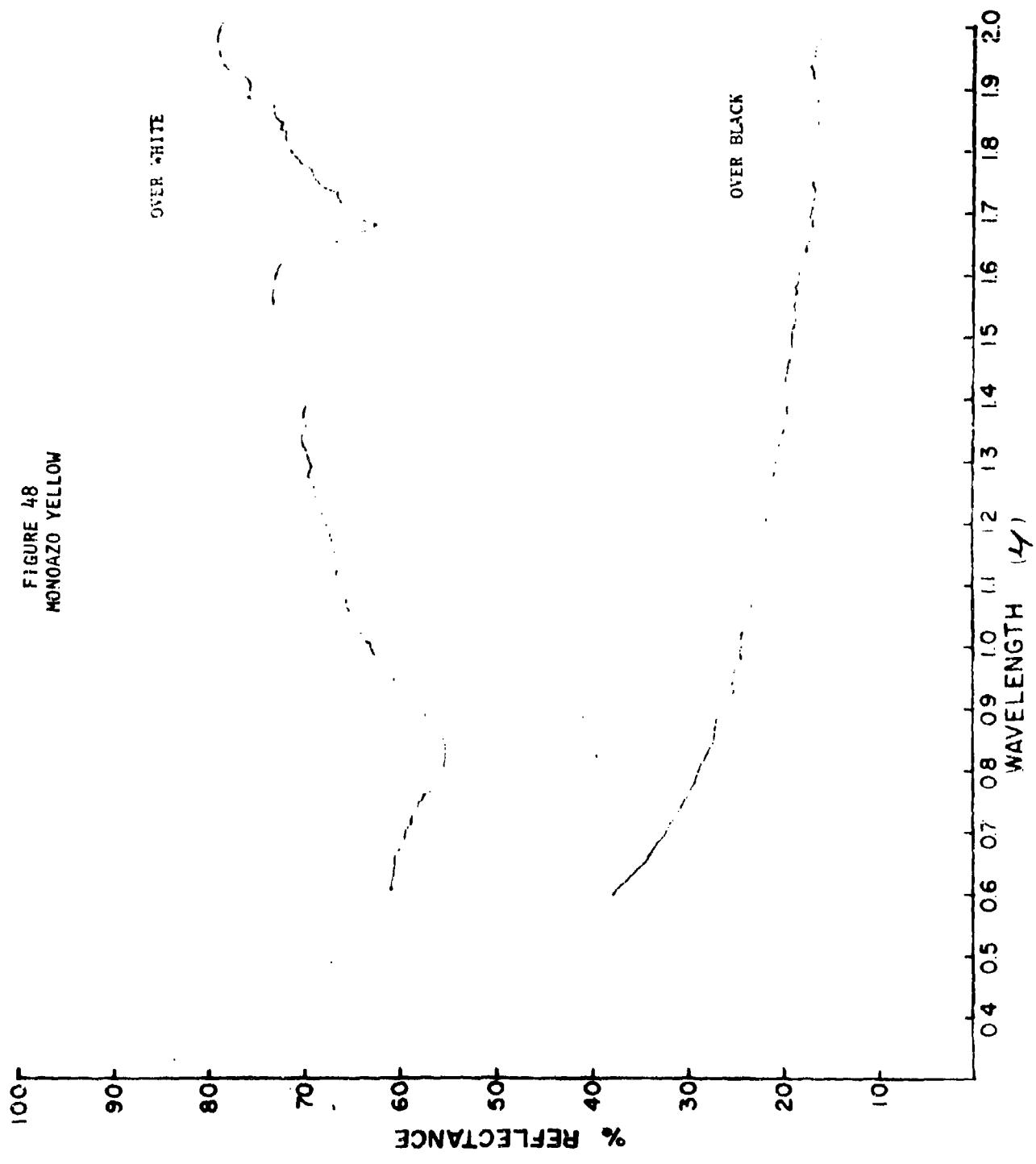


FIGURE 48  
MONOAZO YELLOW



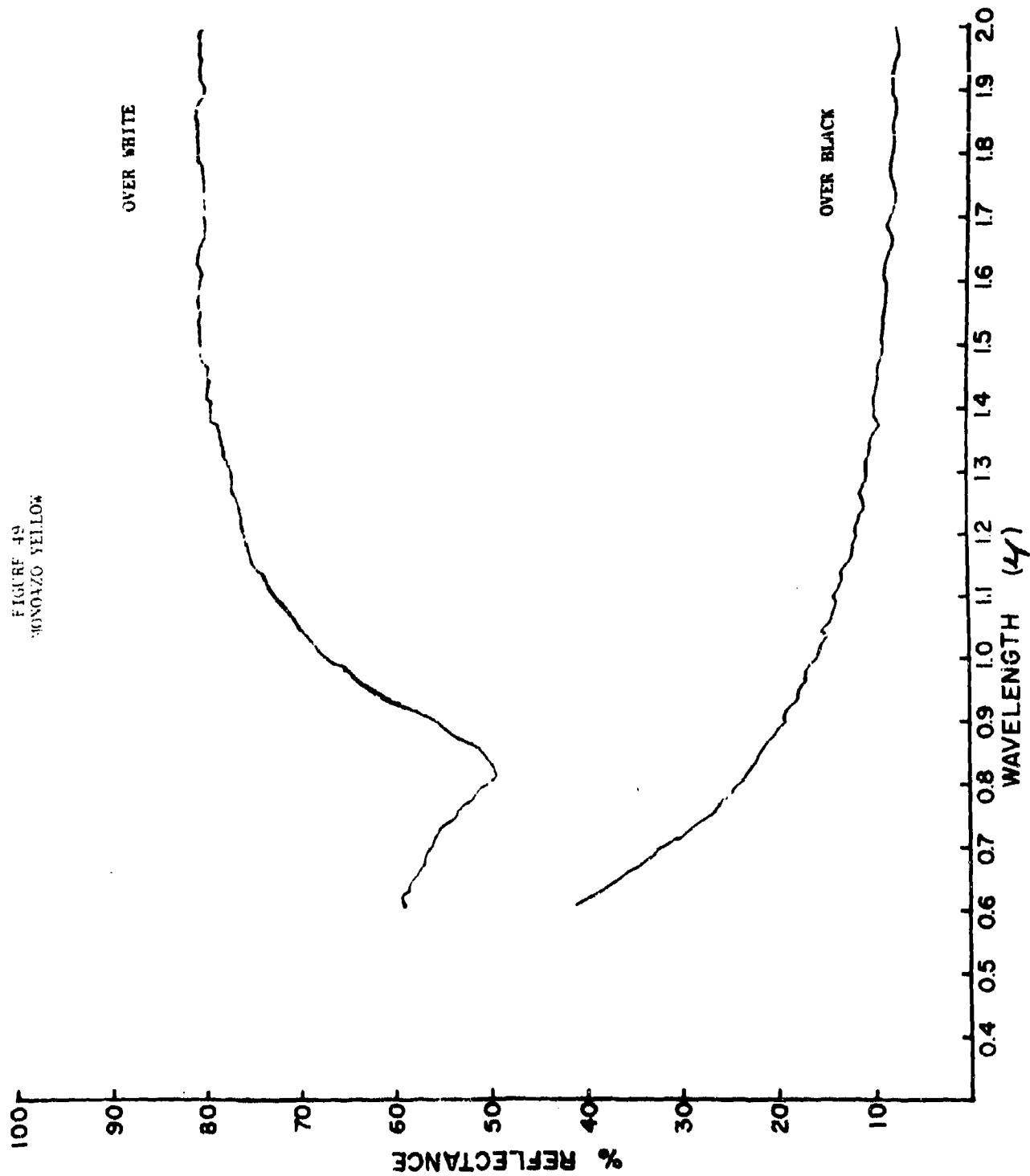
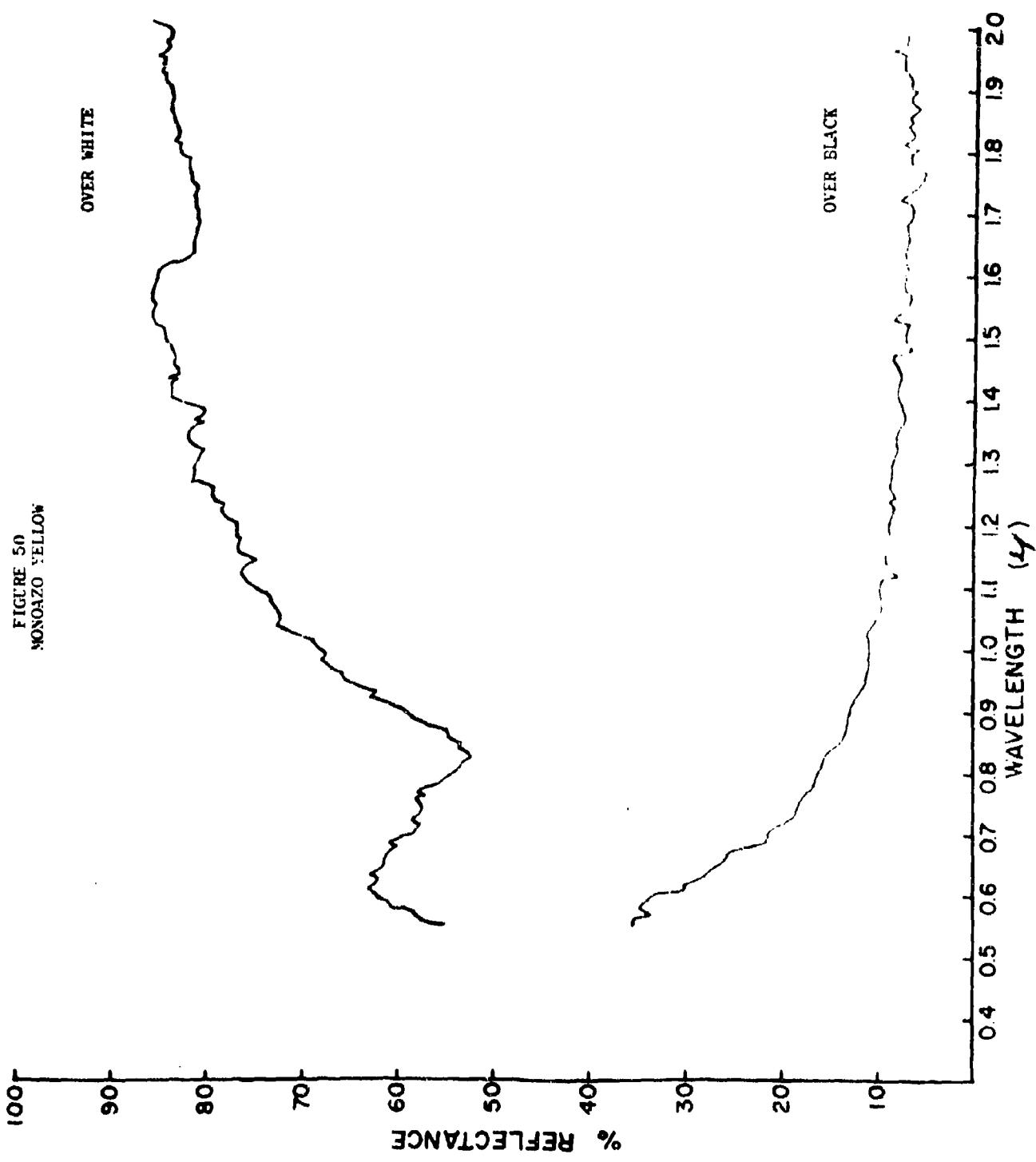
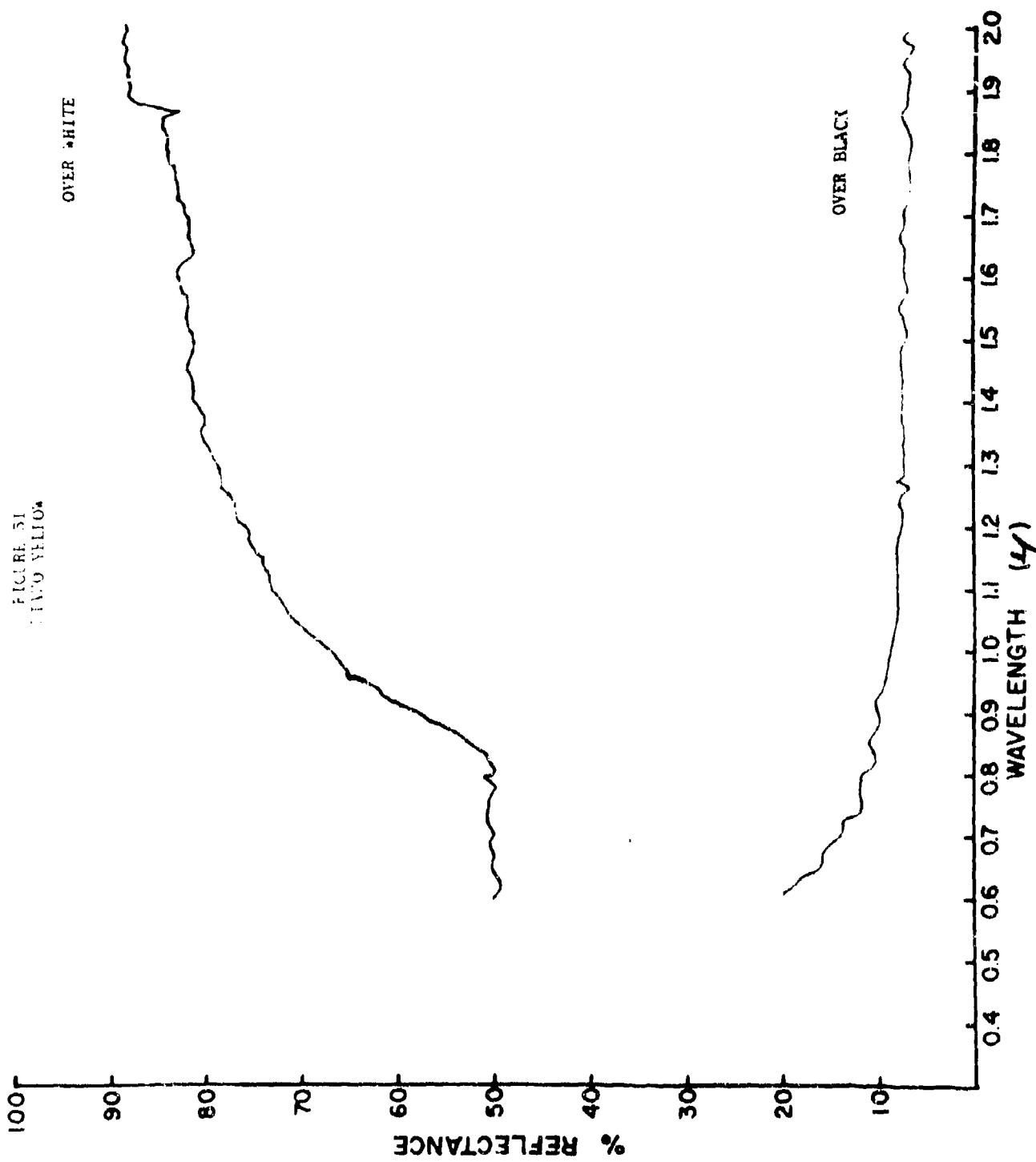


FIGURE 50  
MONOAZO "YELLOW"





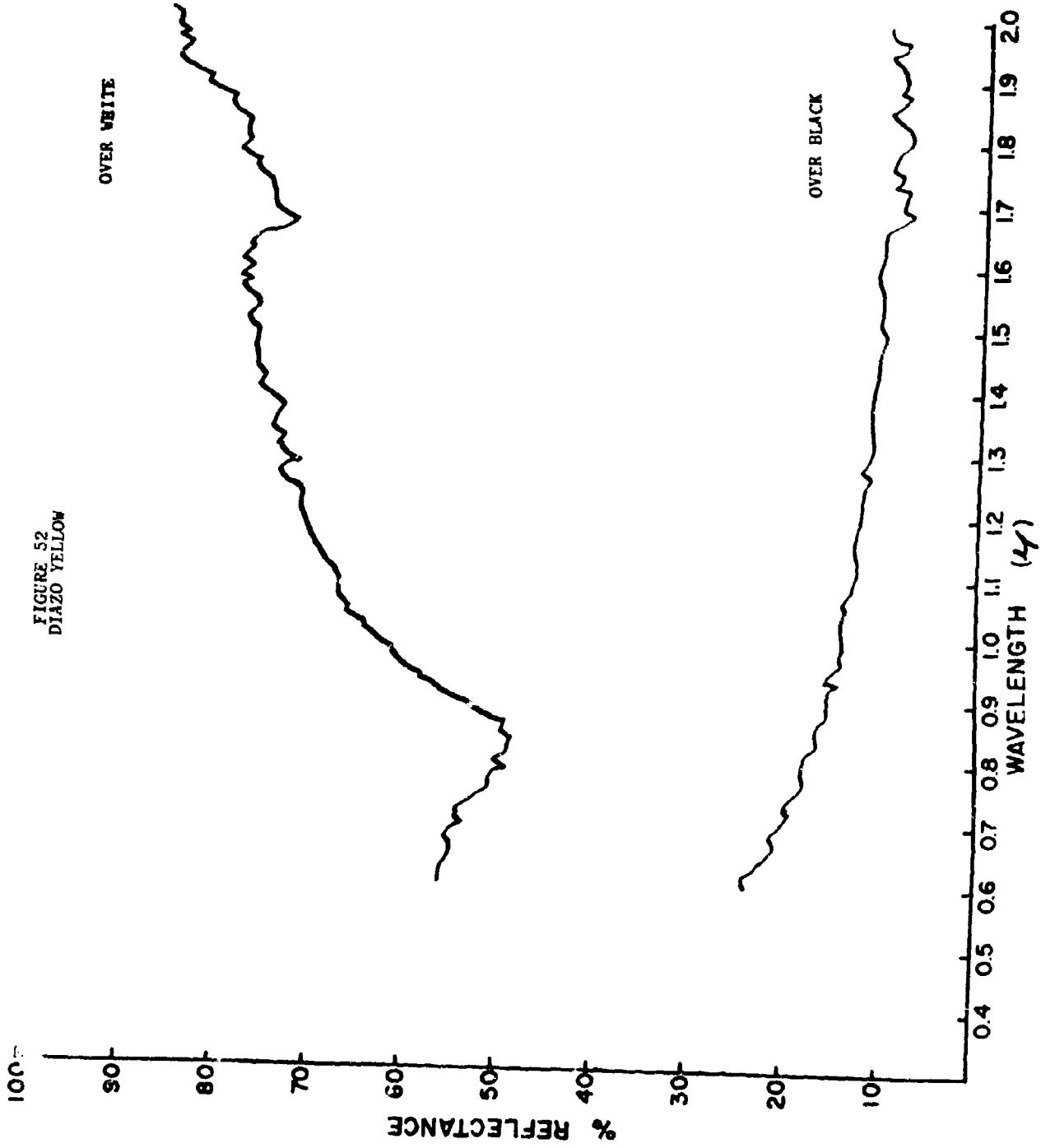


FIGURE 53  
ACETOACETIC ARYLIDE YELLOW

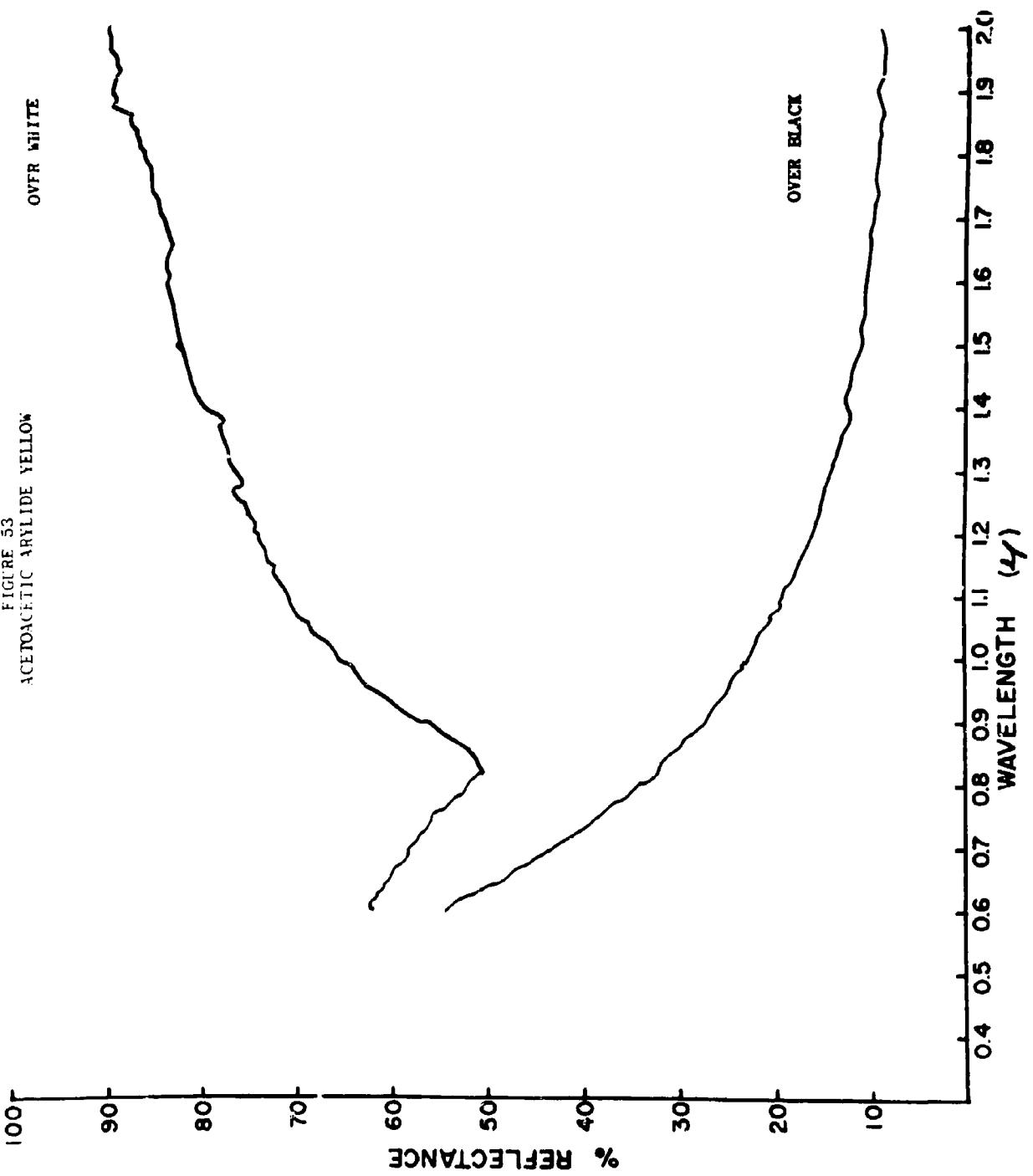


FIGURE 54  
ACETOACETIC ARYLIDE YELLOW

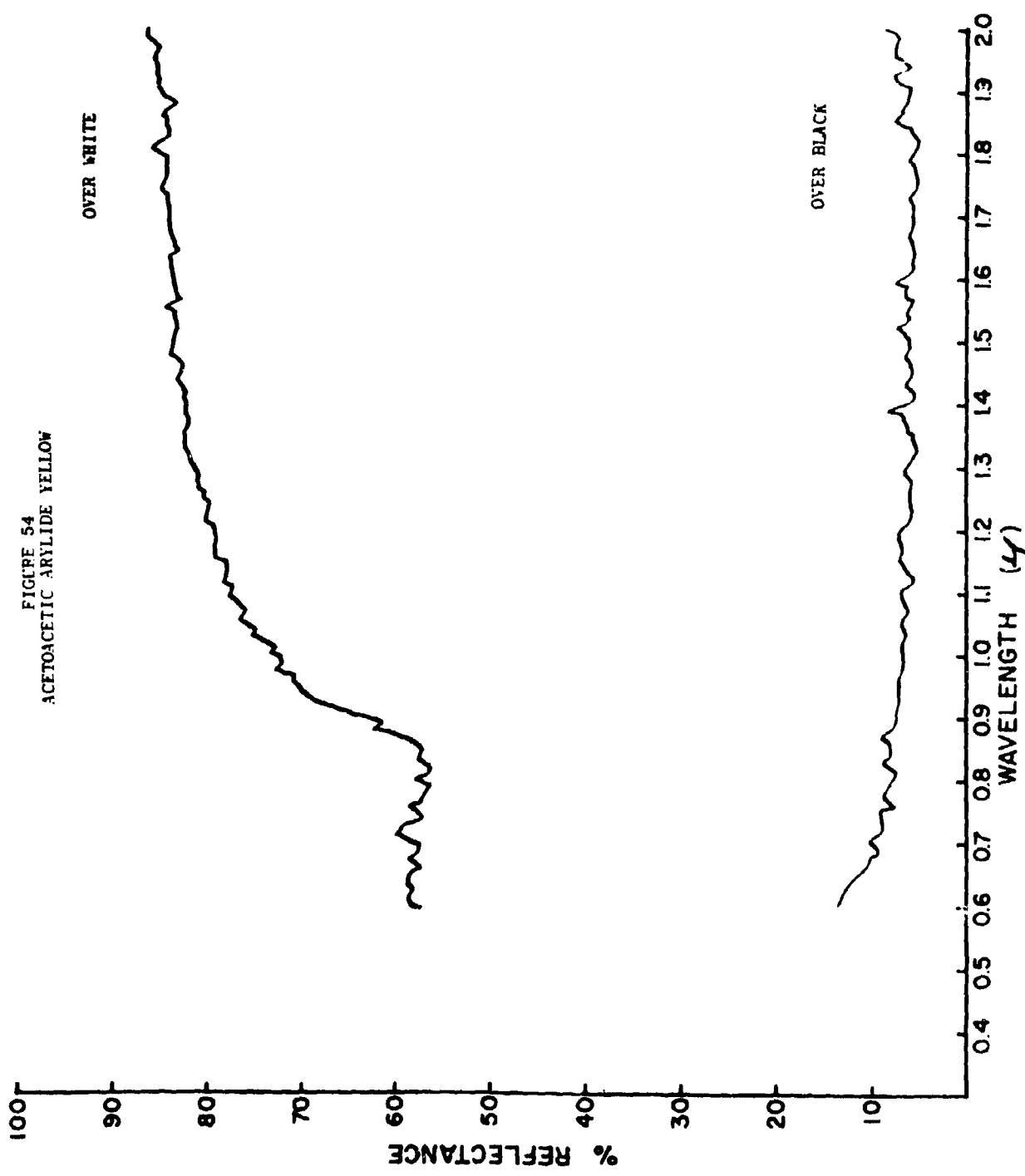


FIGURE 55  
ANTHRAHYDROXYMIDINE YELLOW

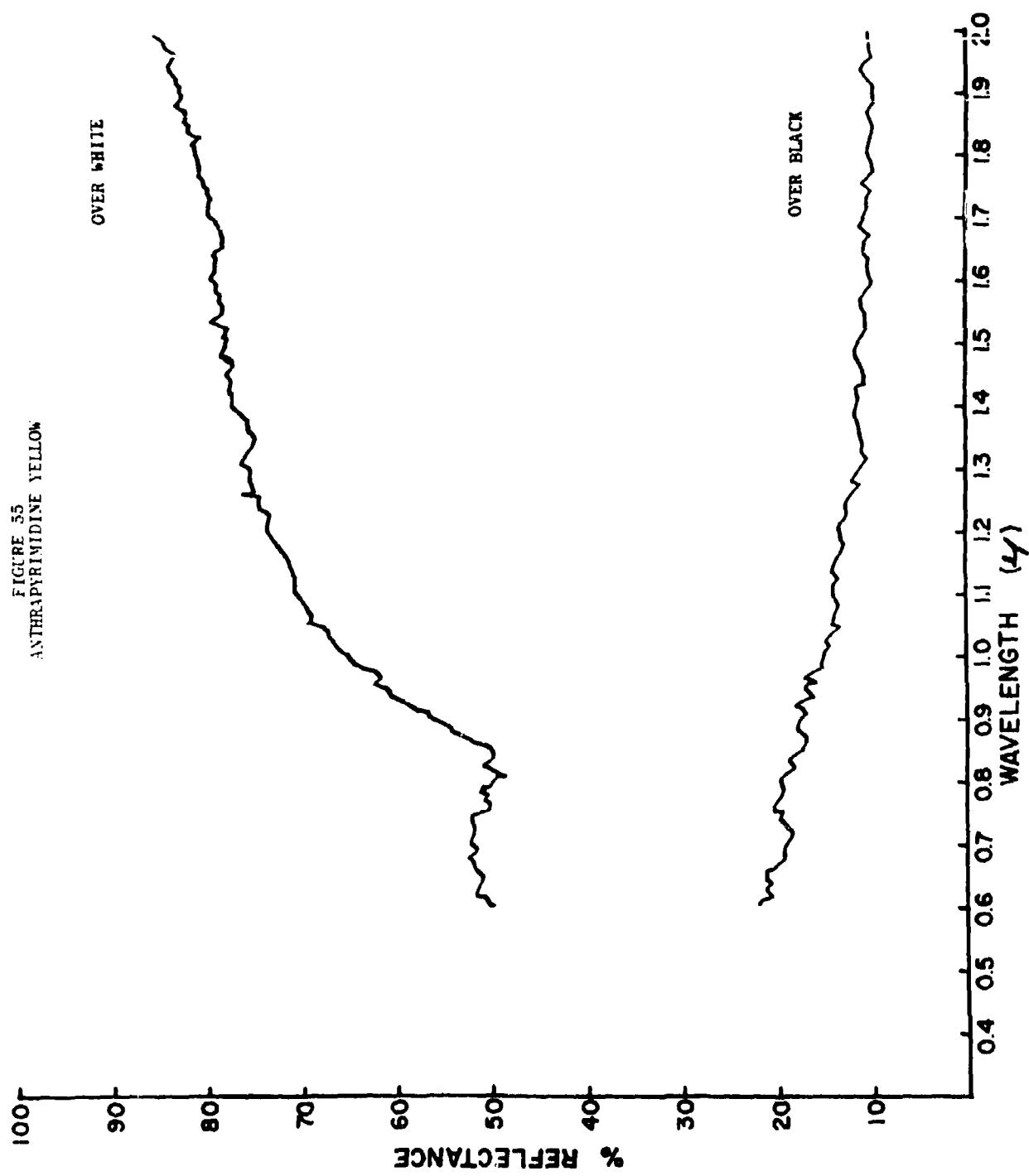


FIGURE 56  
ANTHRAHYDROXYIMIDINE YELLOW

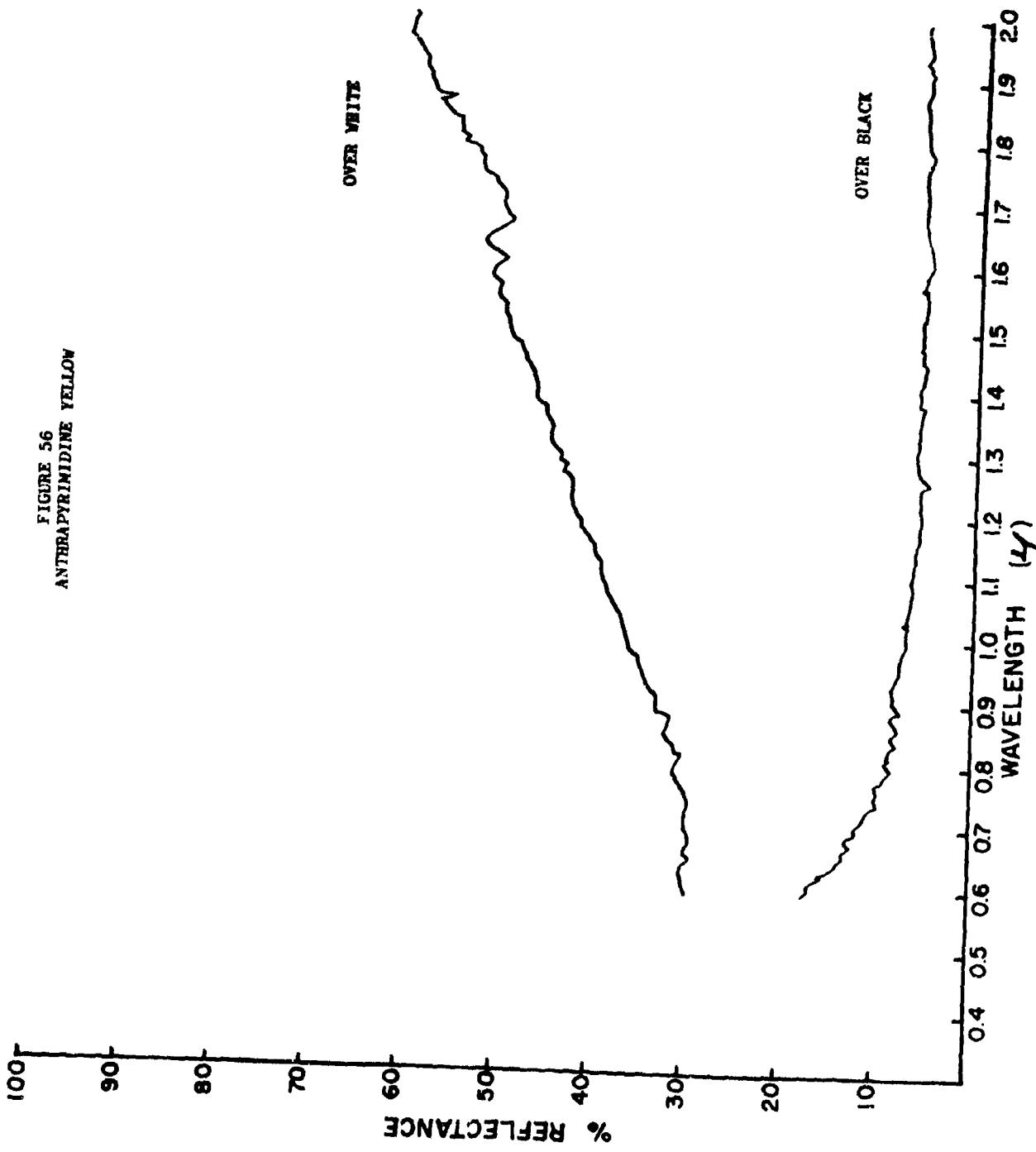
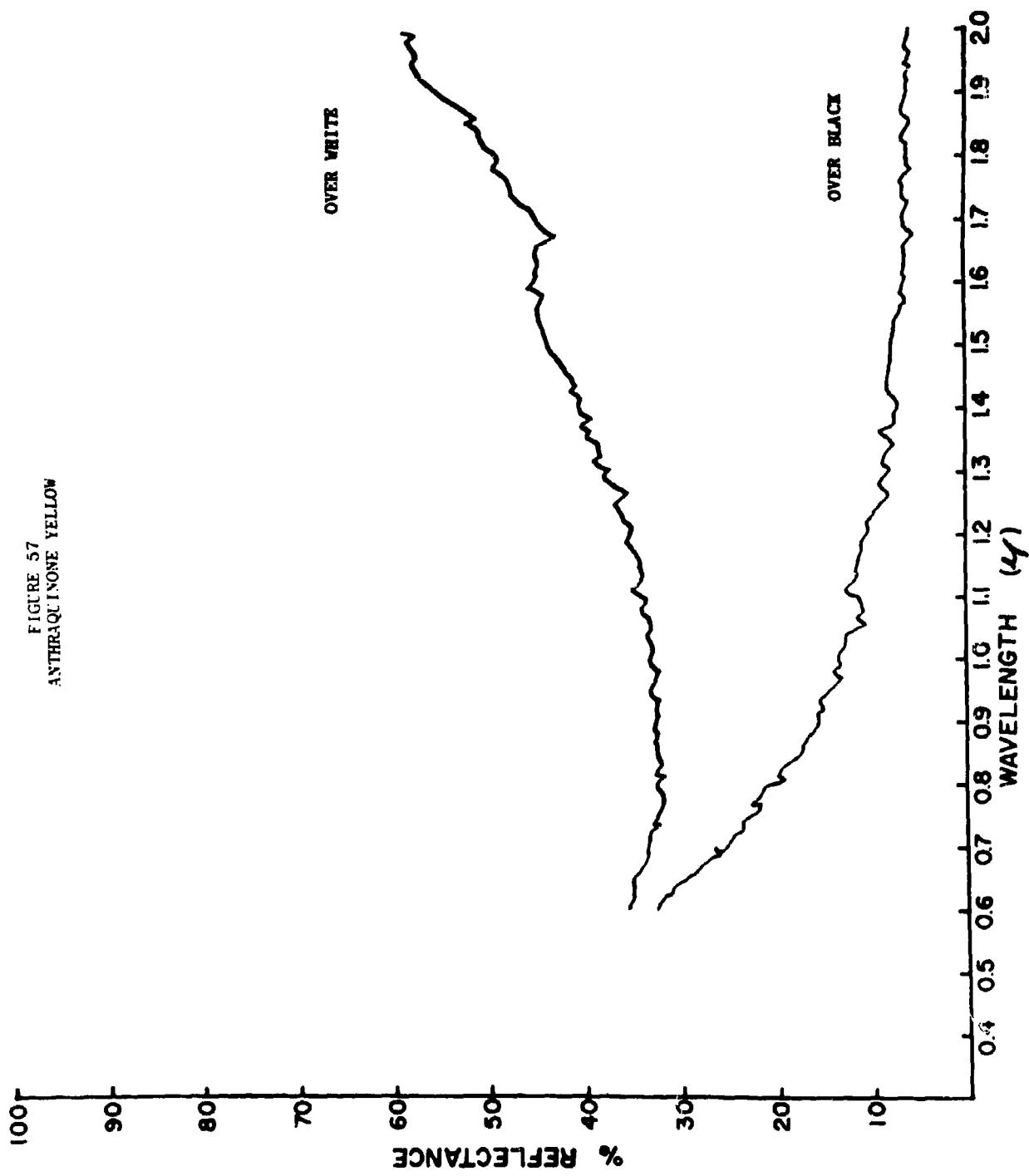


FIGURE 57  
ANTHRAQUINONE YELLOW



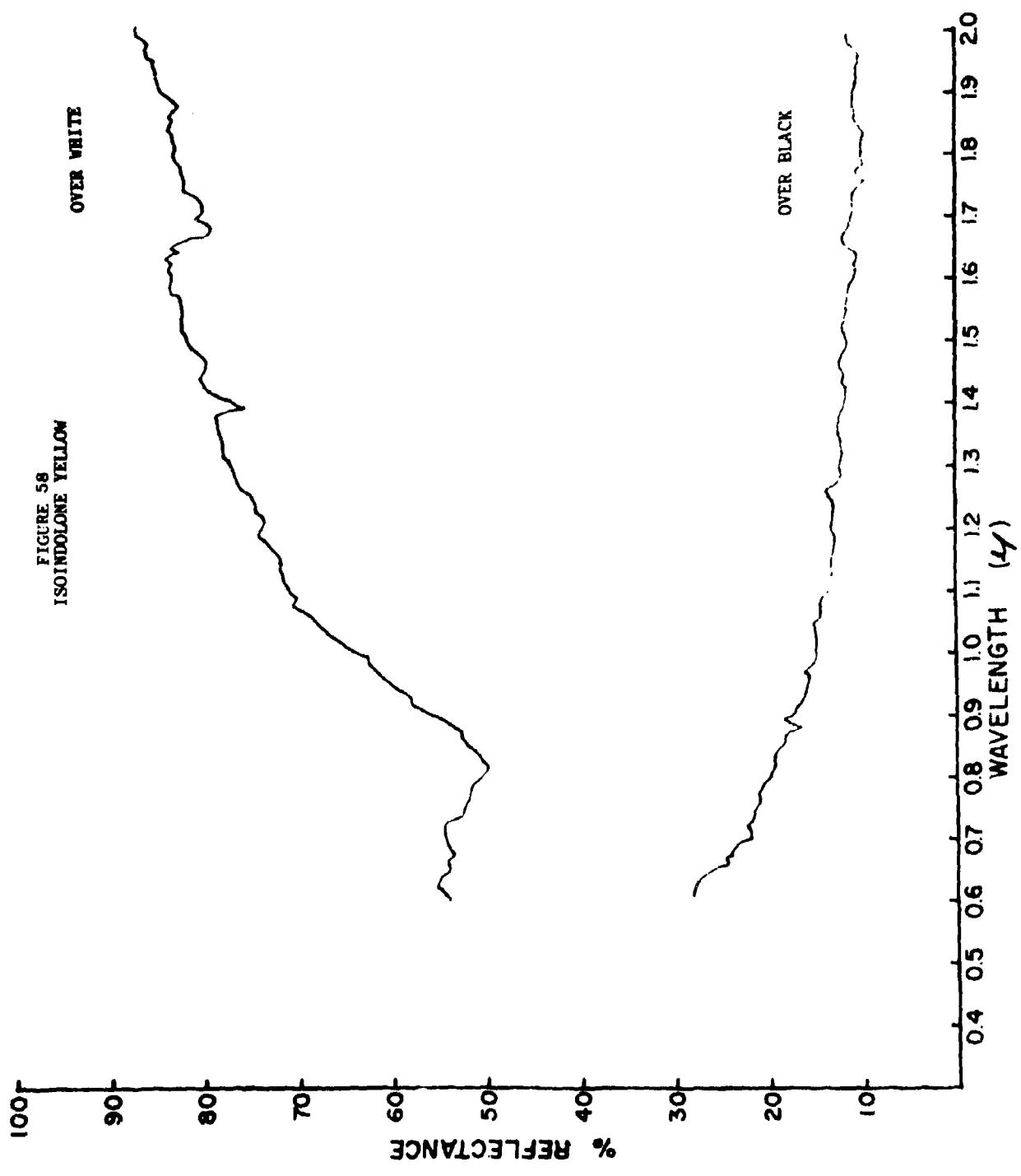


FIGURE 59  
QUINACRIDONE YELLOW

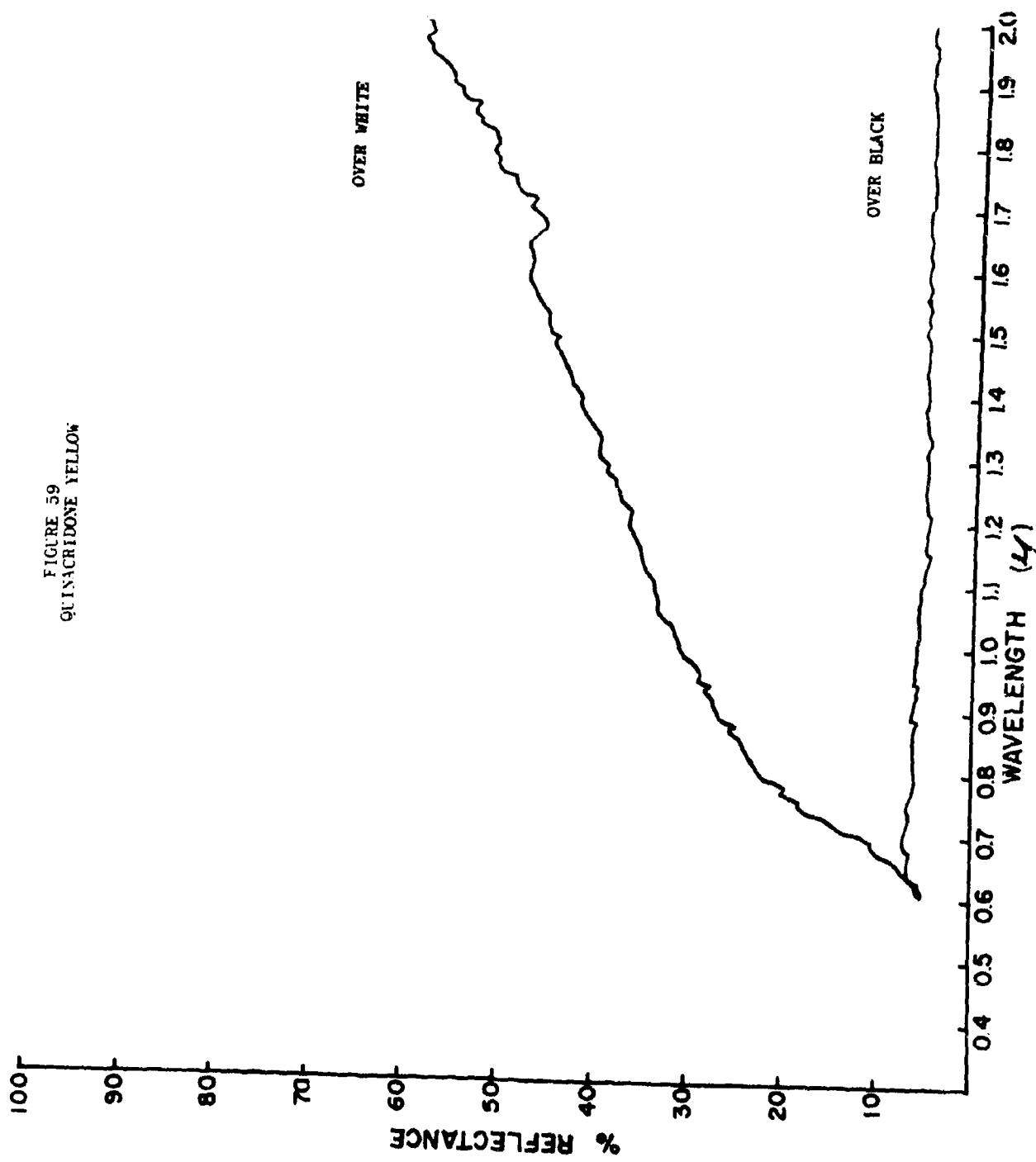


FIGURE 60  
MONOAZO GREEN

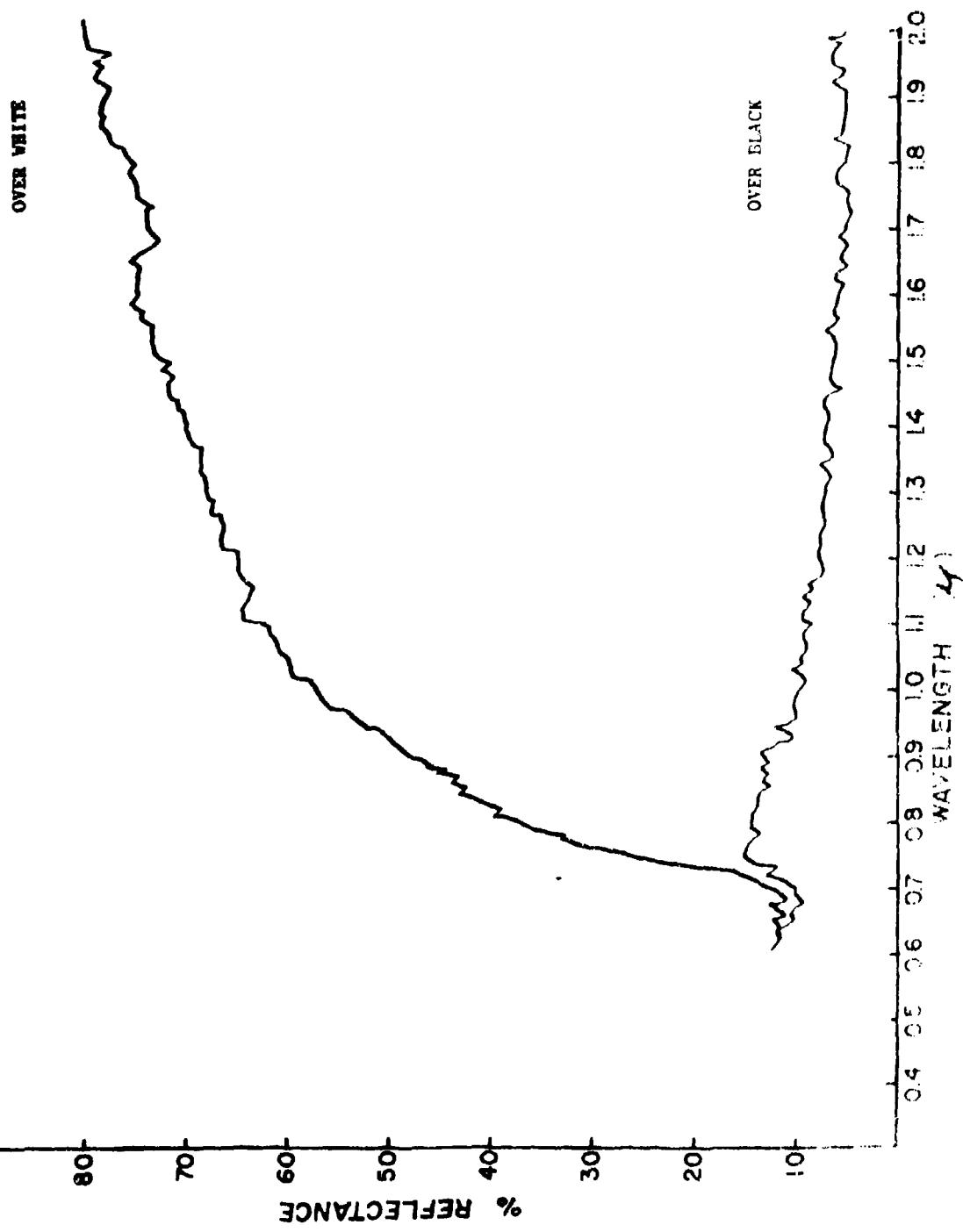


FIGURE 61  
NICKEL AZO GREEN

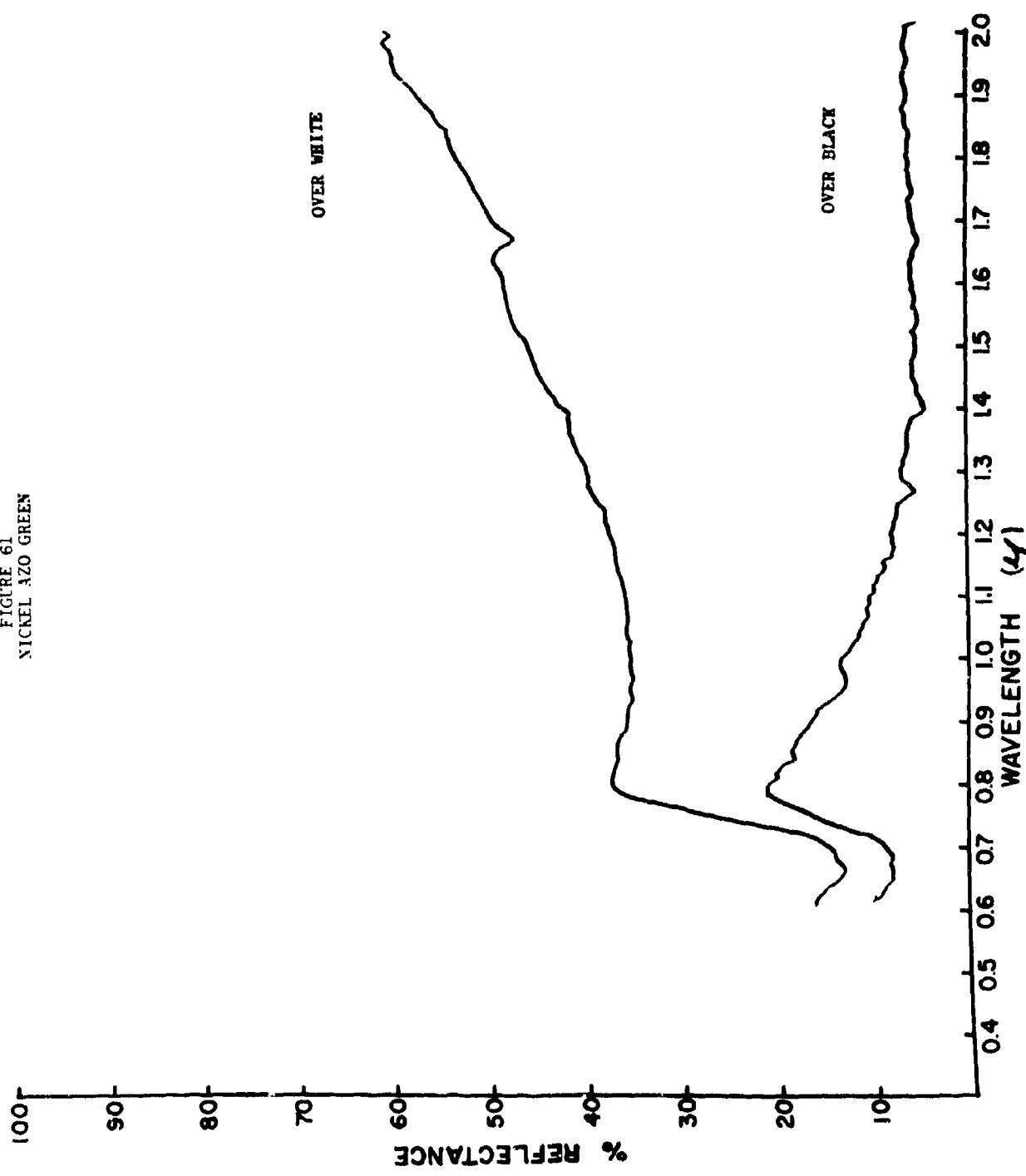
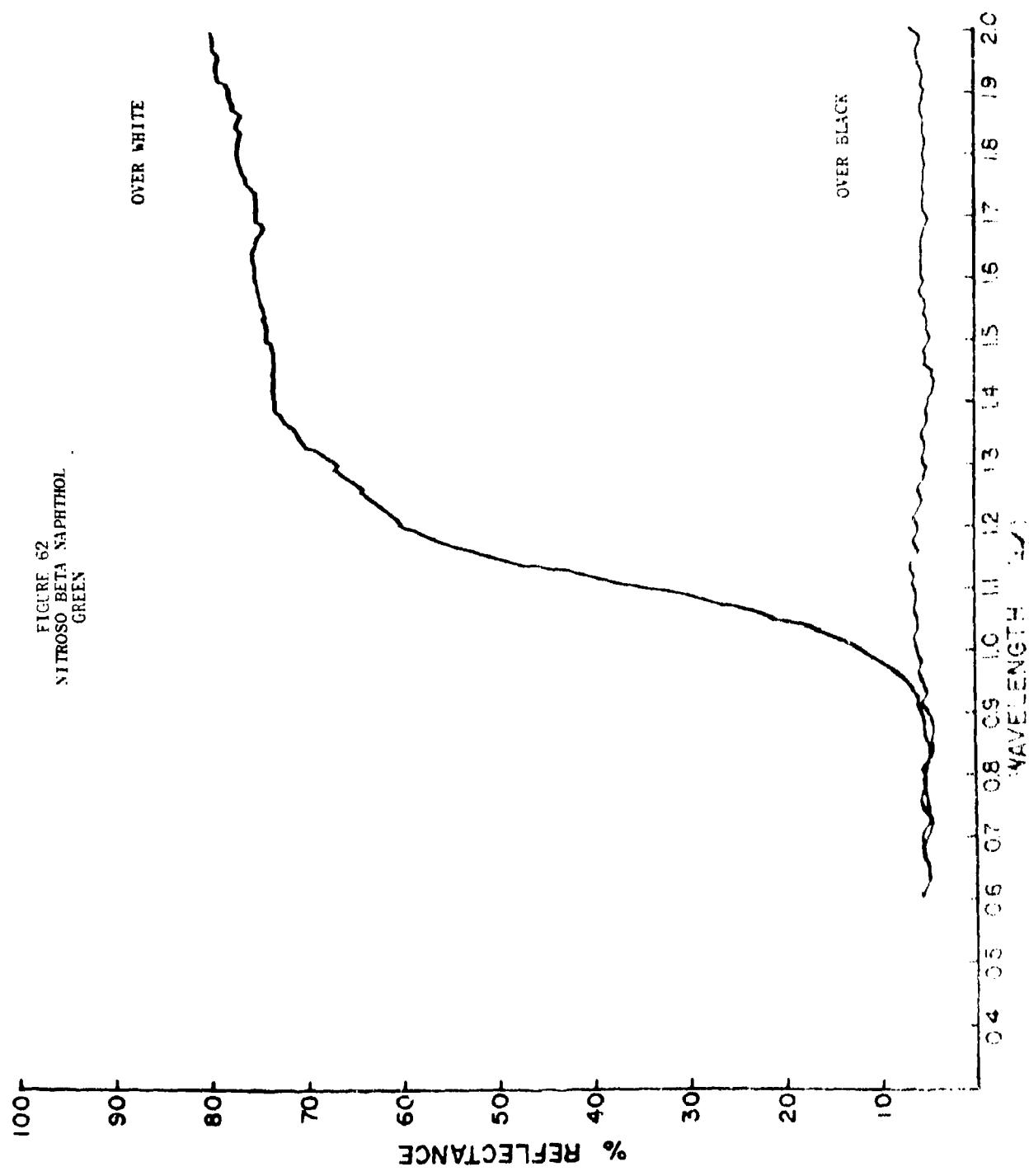
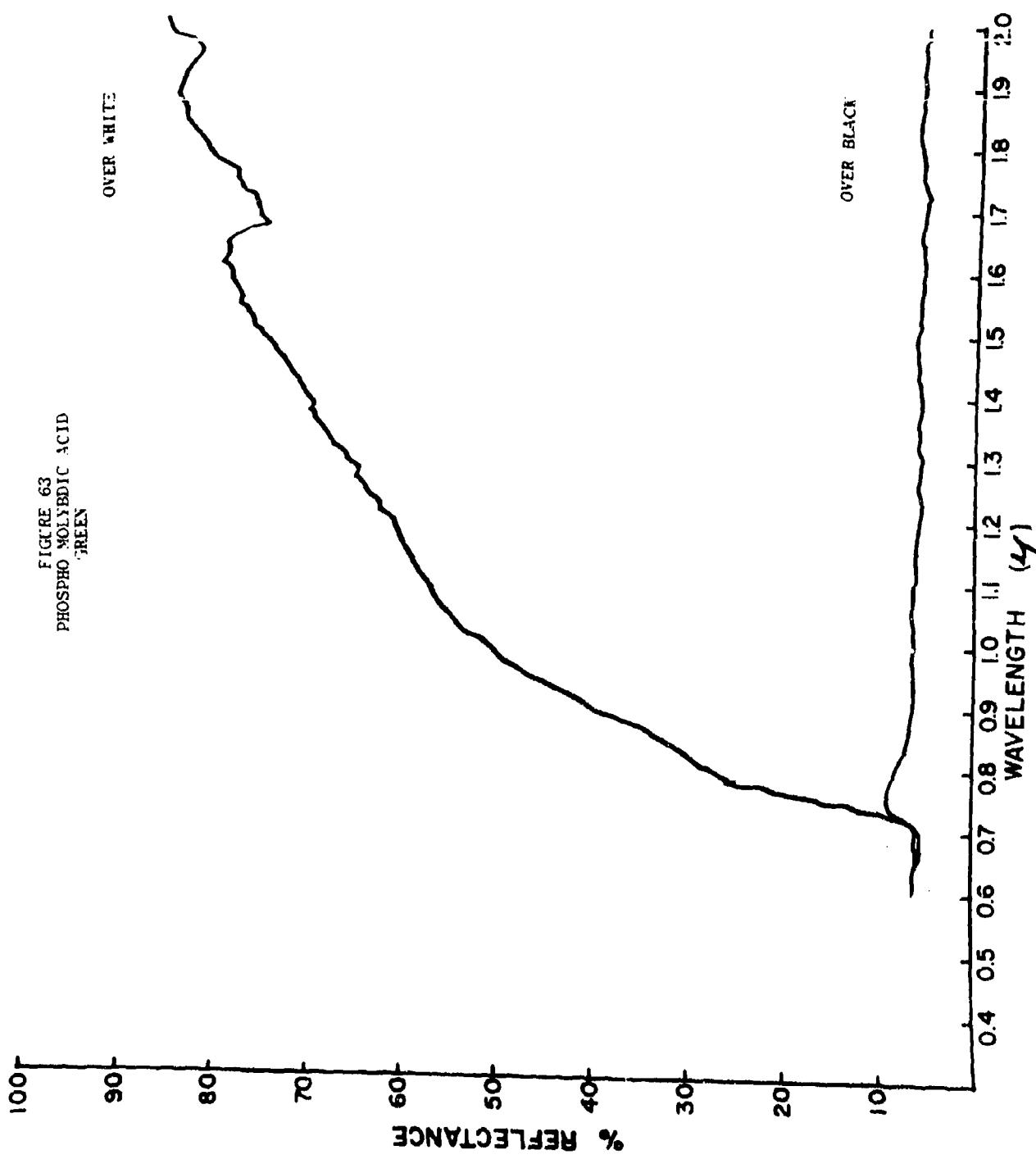


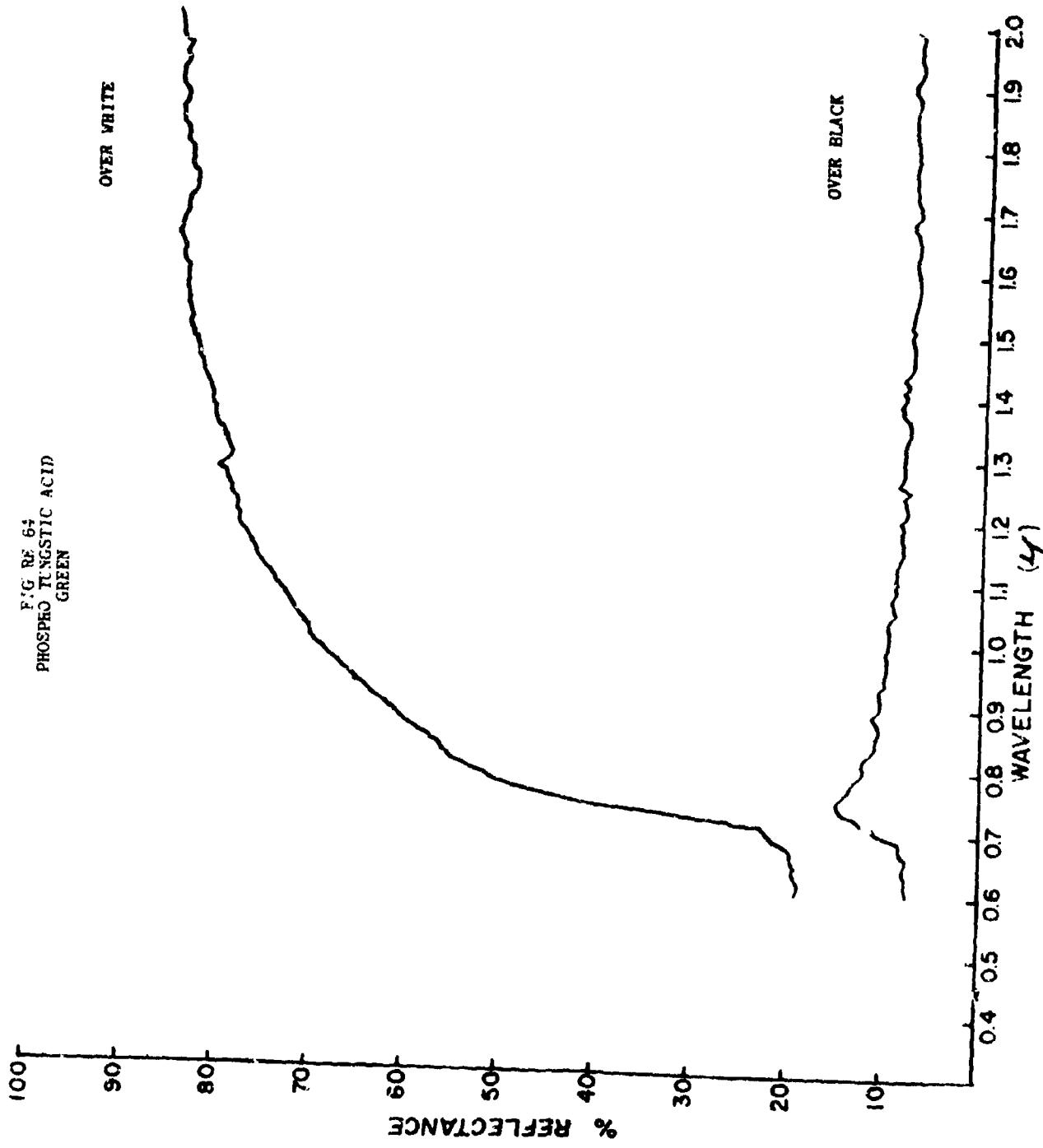
FIGURE 62  
NITROSO BETA NA PHTHOL  
GREEN



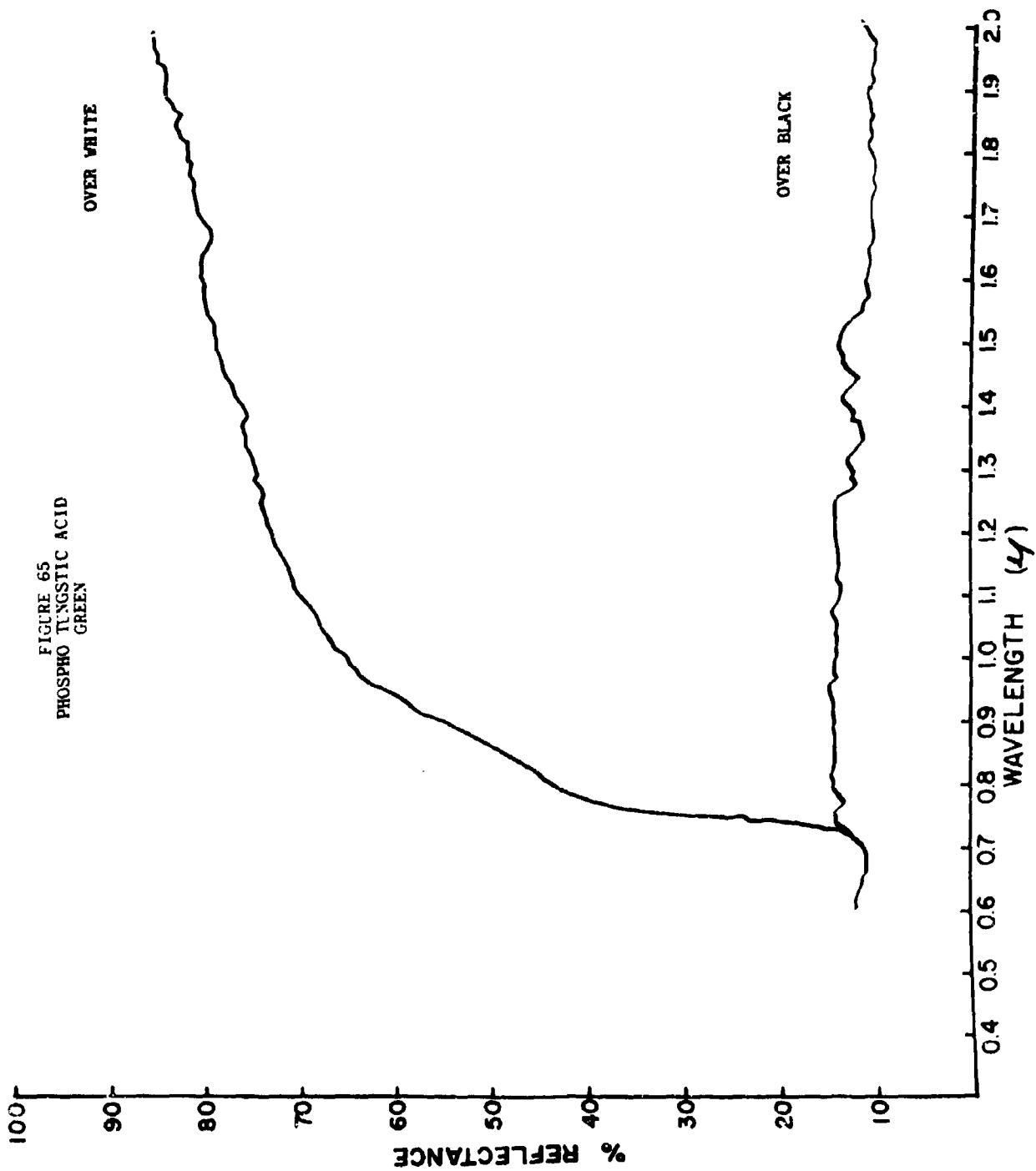


P.G. No 6;  
PHOSPHOMANGSTIC ACID  
GREEN

OVER WHITE



OVER BLACK



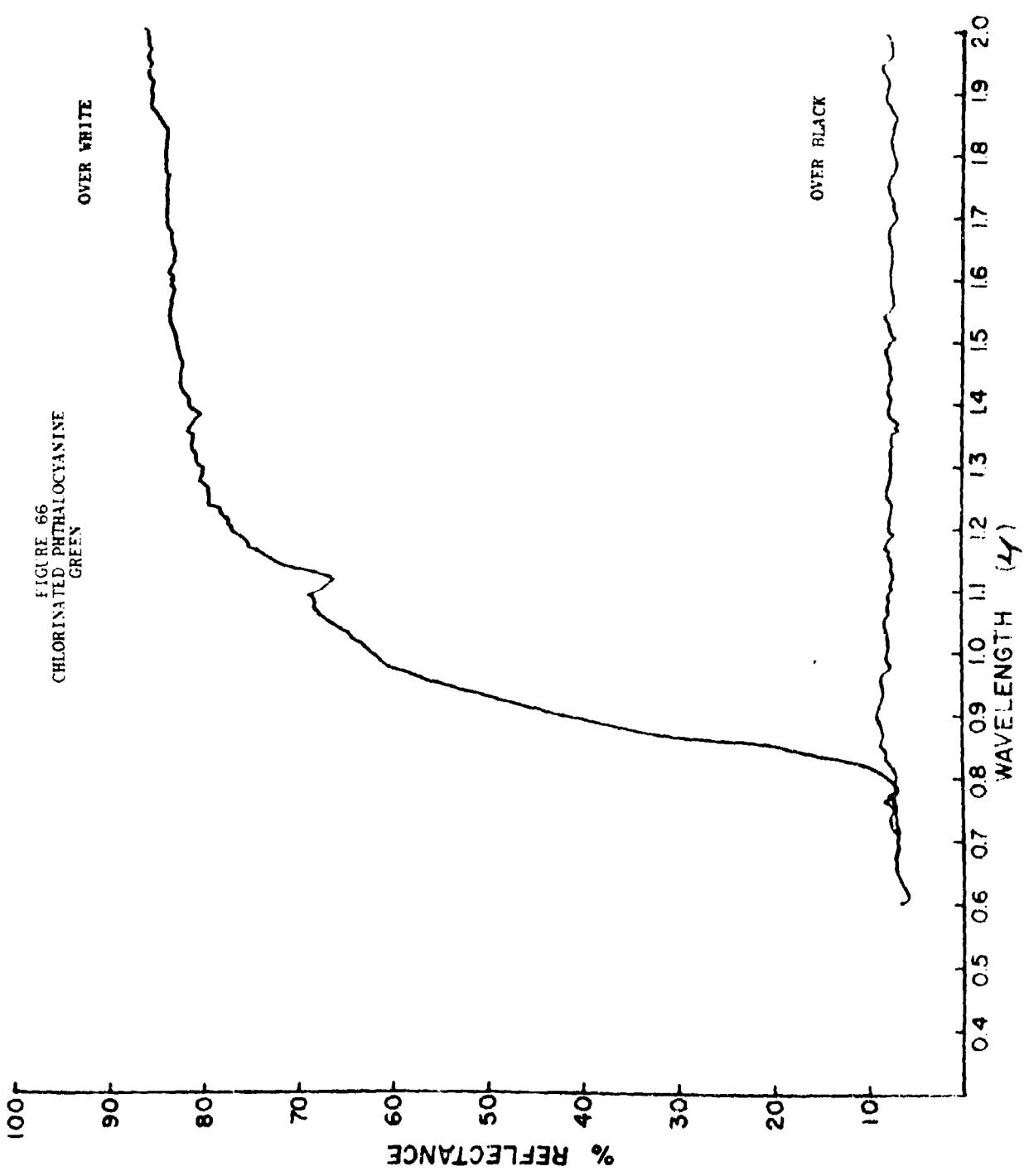


FIGURE 67  
CHLORINATED PHTHALOCYANINE  
GREEN

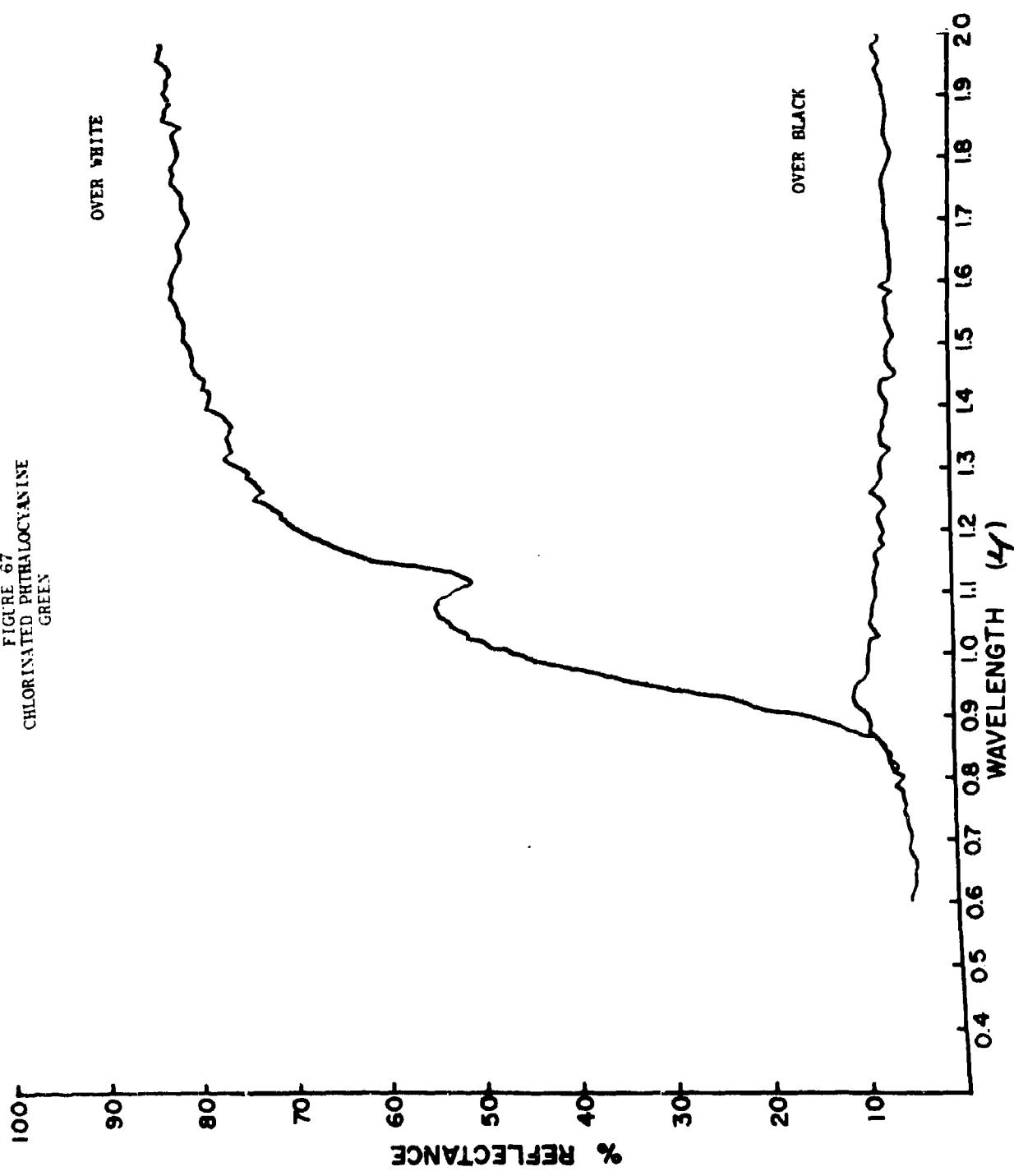
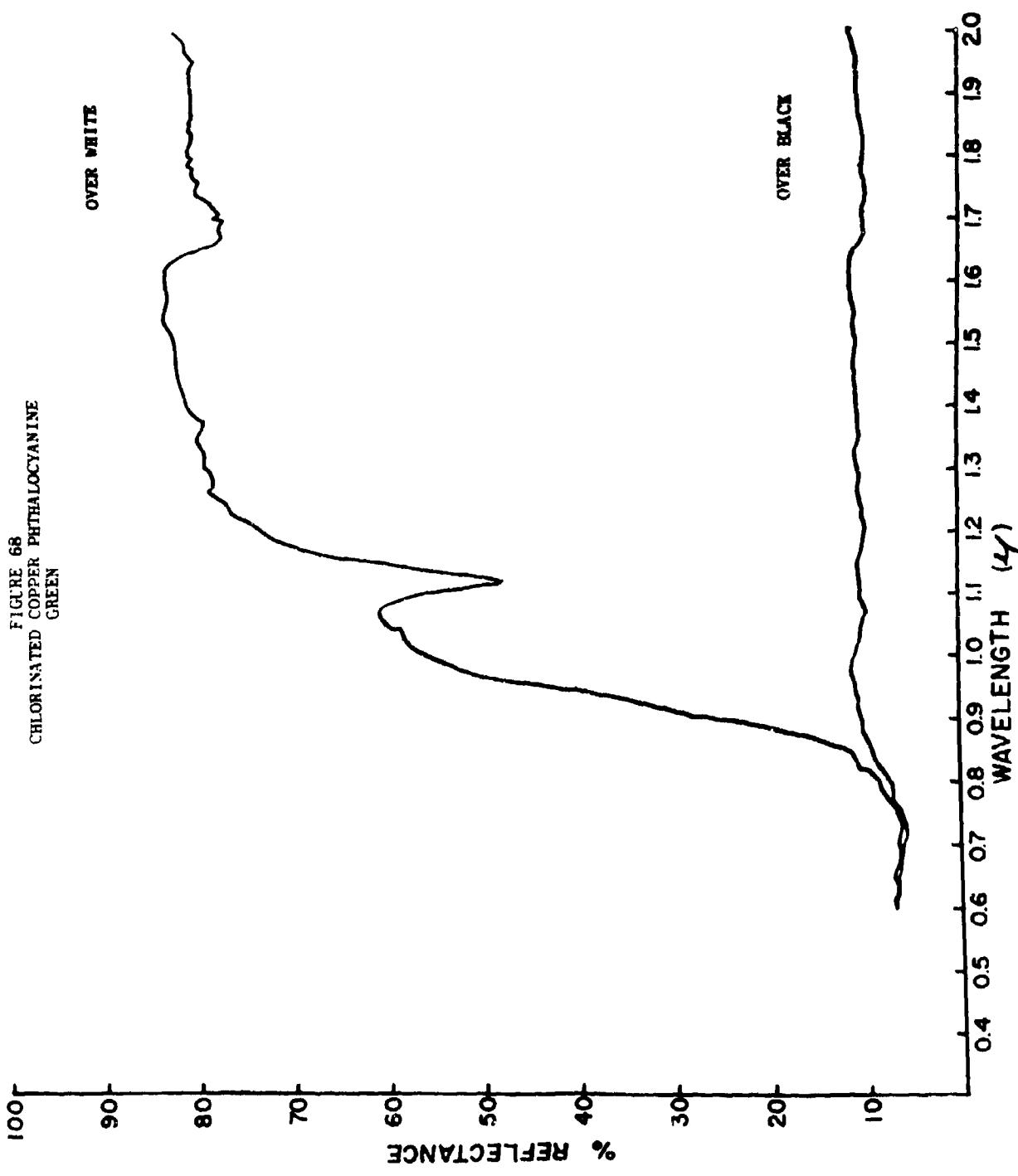


FIGURE 68  
CHLORINATED COPPER PHTHALOCYANINE  
GREEN



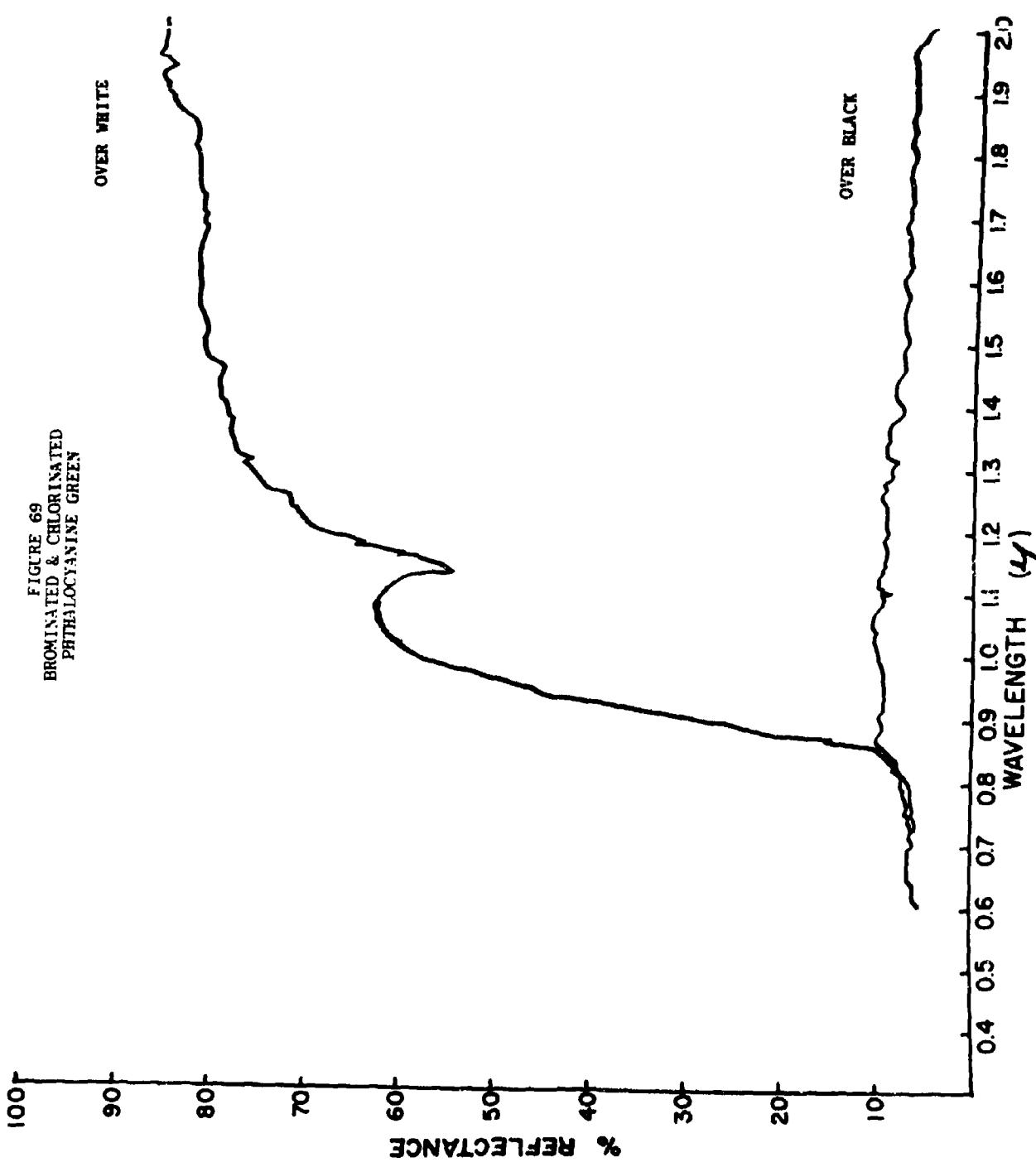


FIGURE 70  
BROMINATED & CHLORINATED  
PHTHALOCYANINE GFLEN

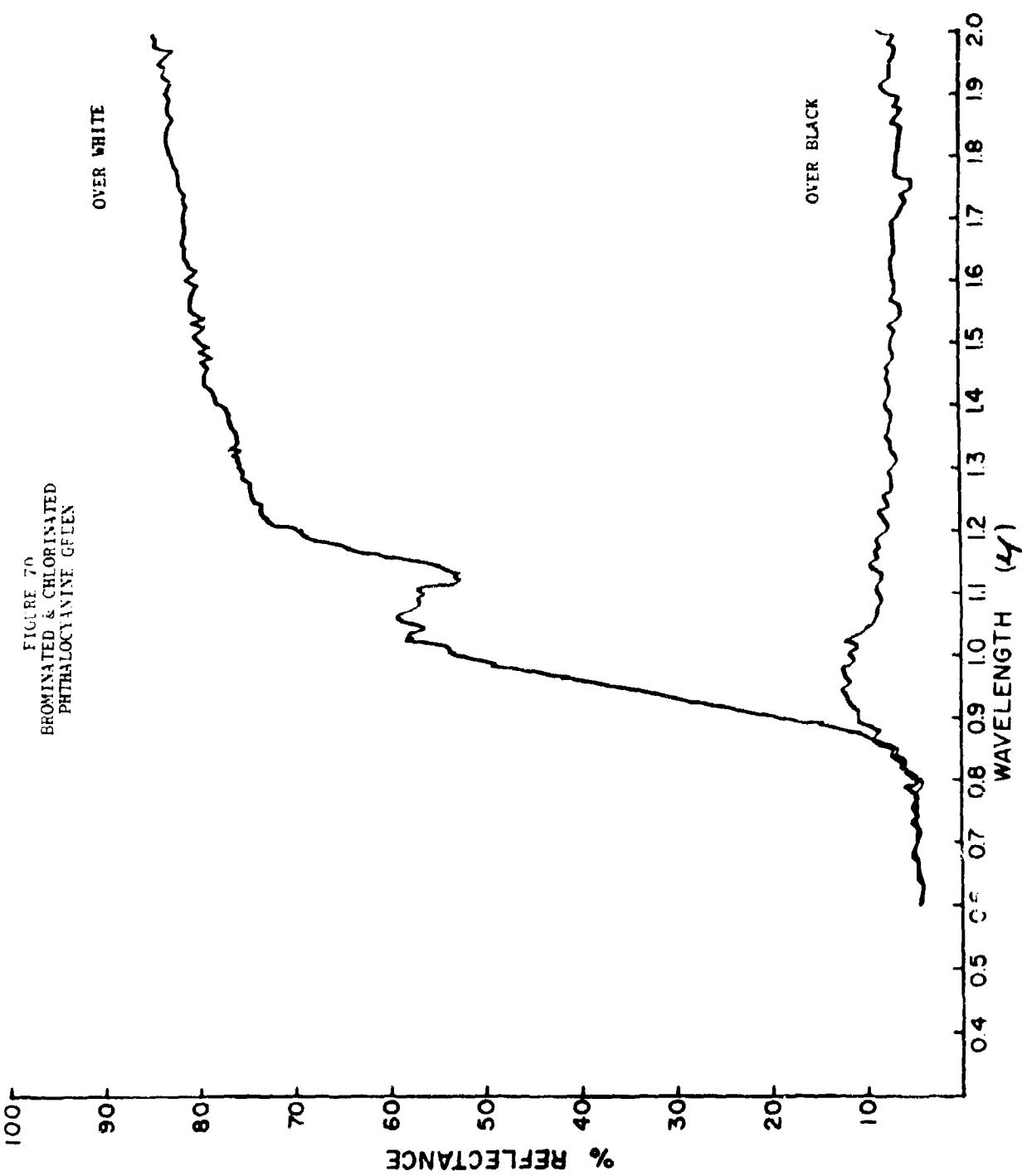


FIGURE 71  
ANTHRACITONE BLUE

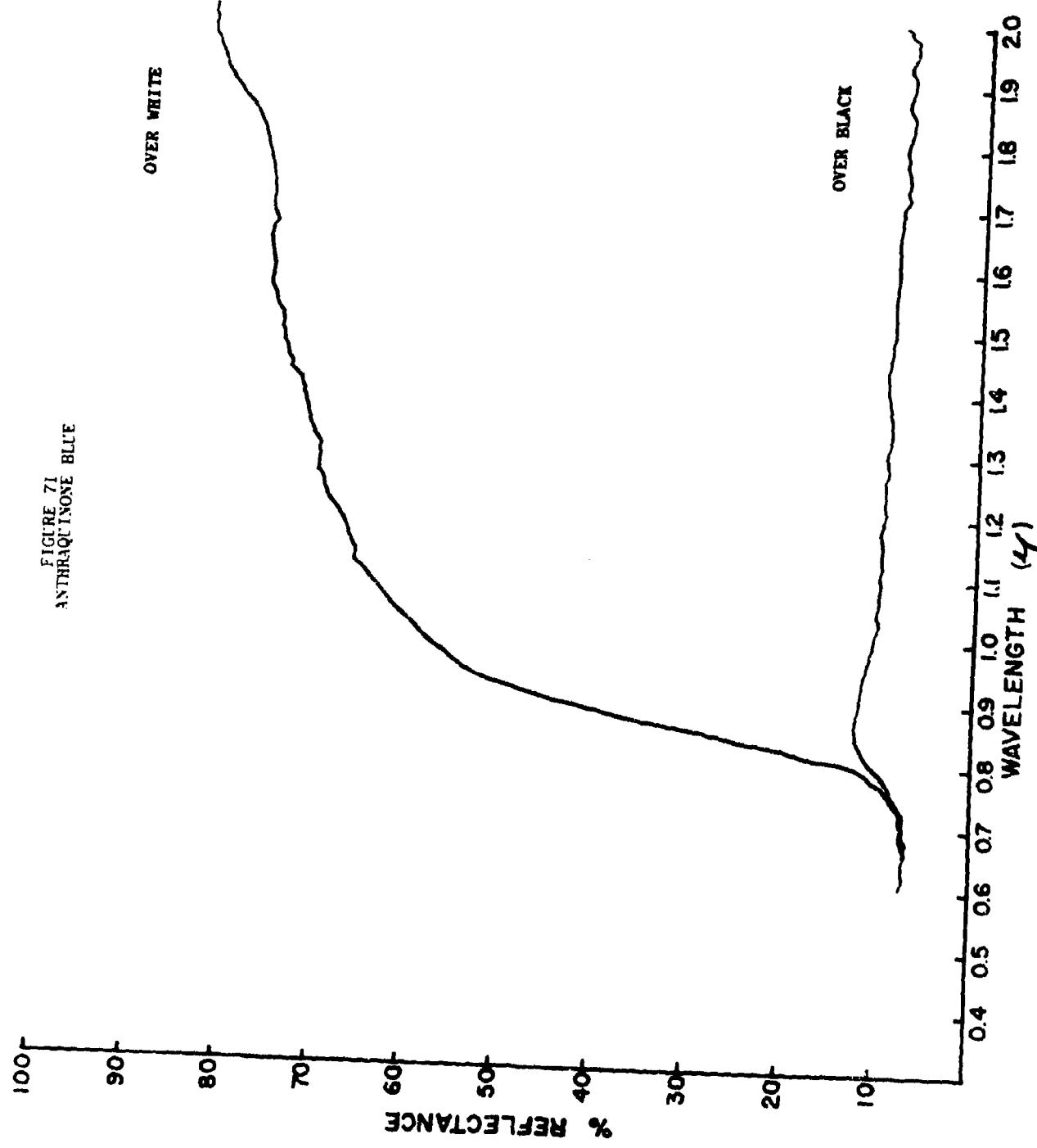


FIGURE 72  
DIAZO BLUE

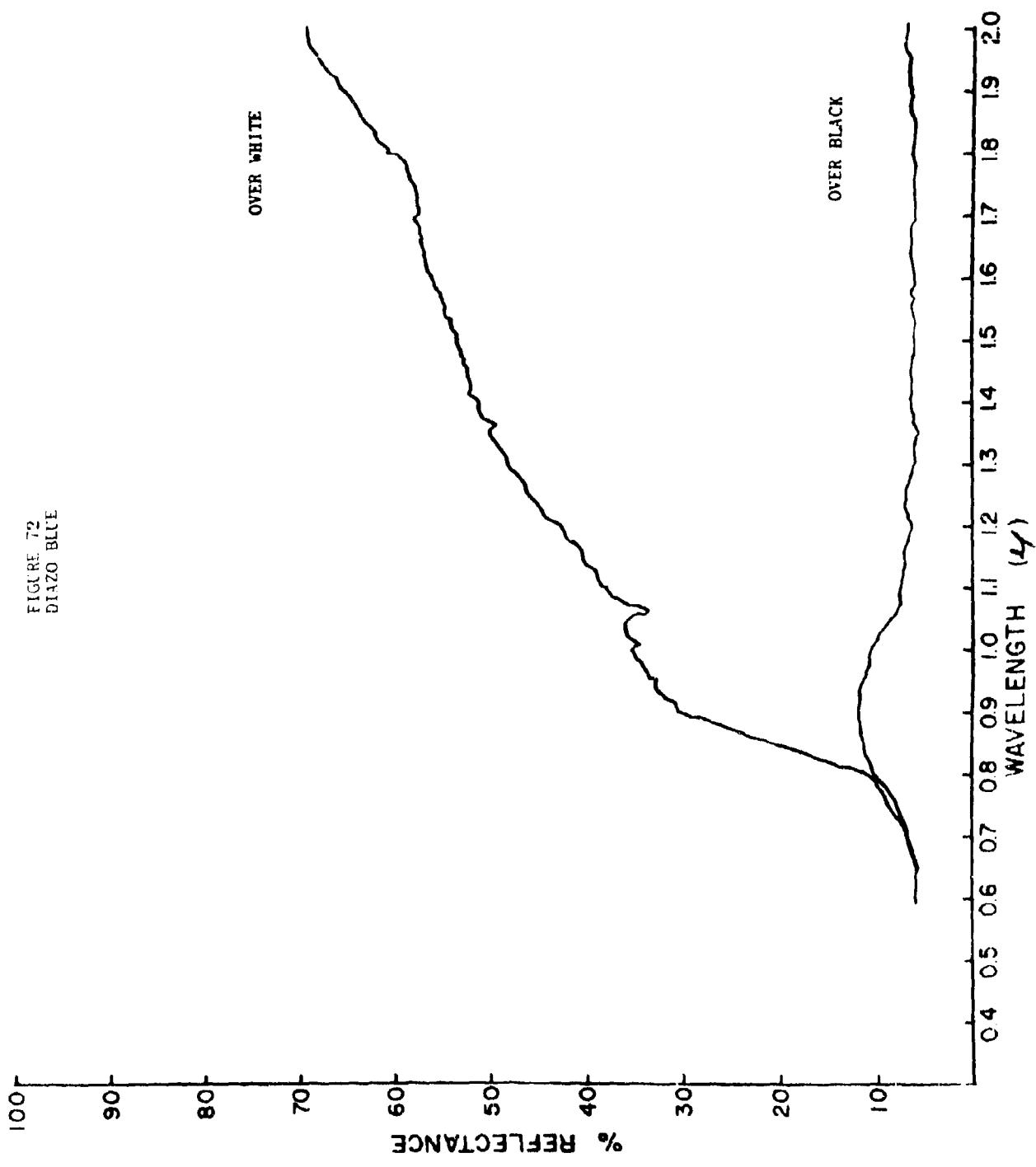


FIGURE 73  
INDANTHRONE BLUE

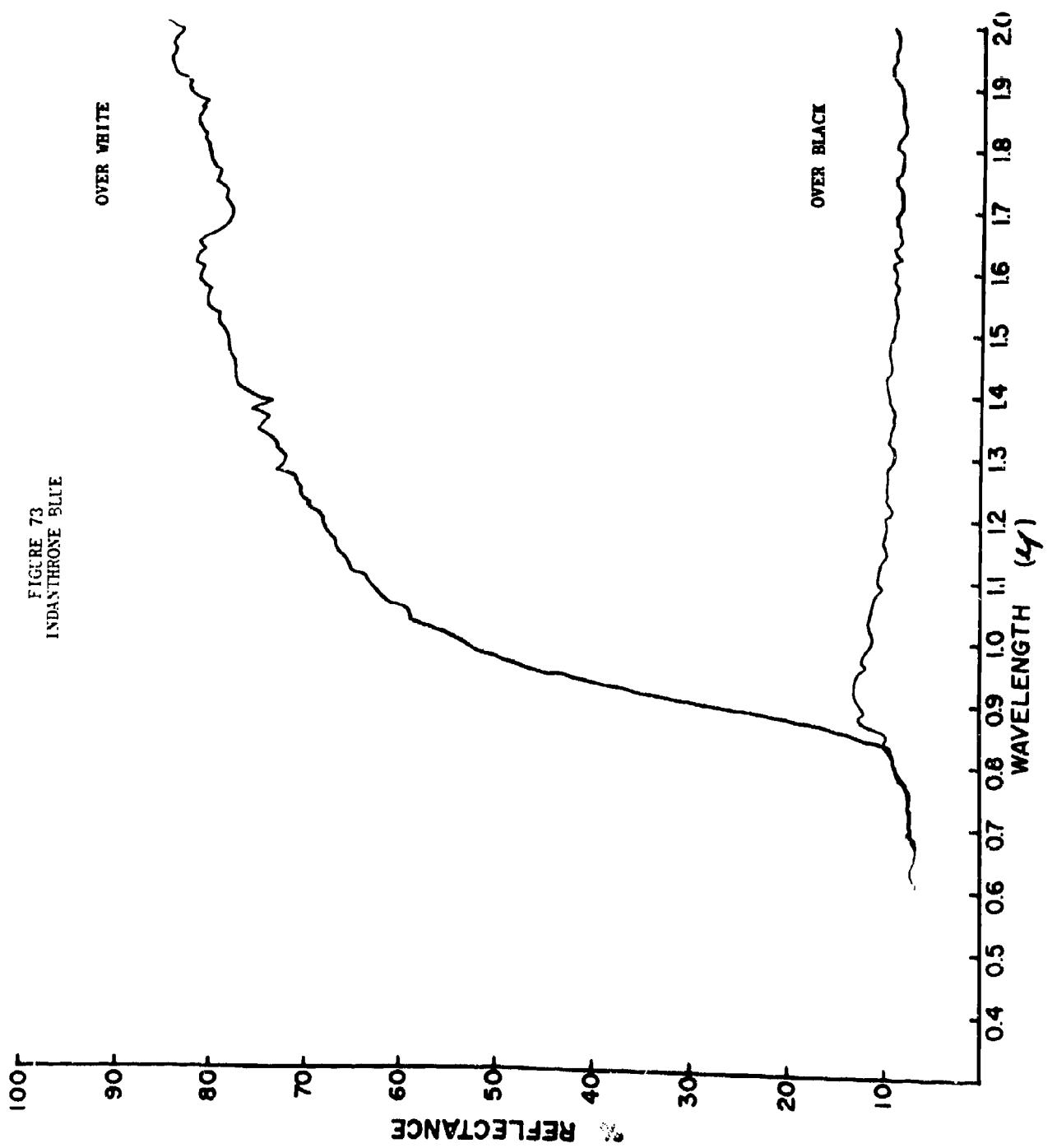
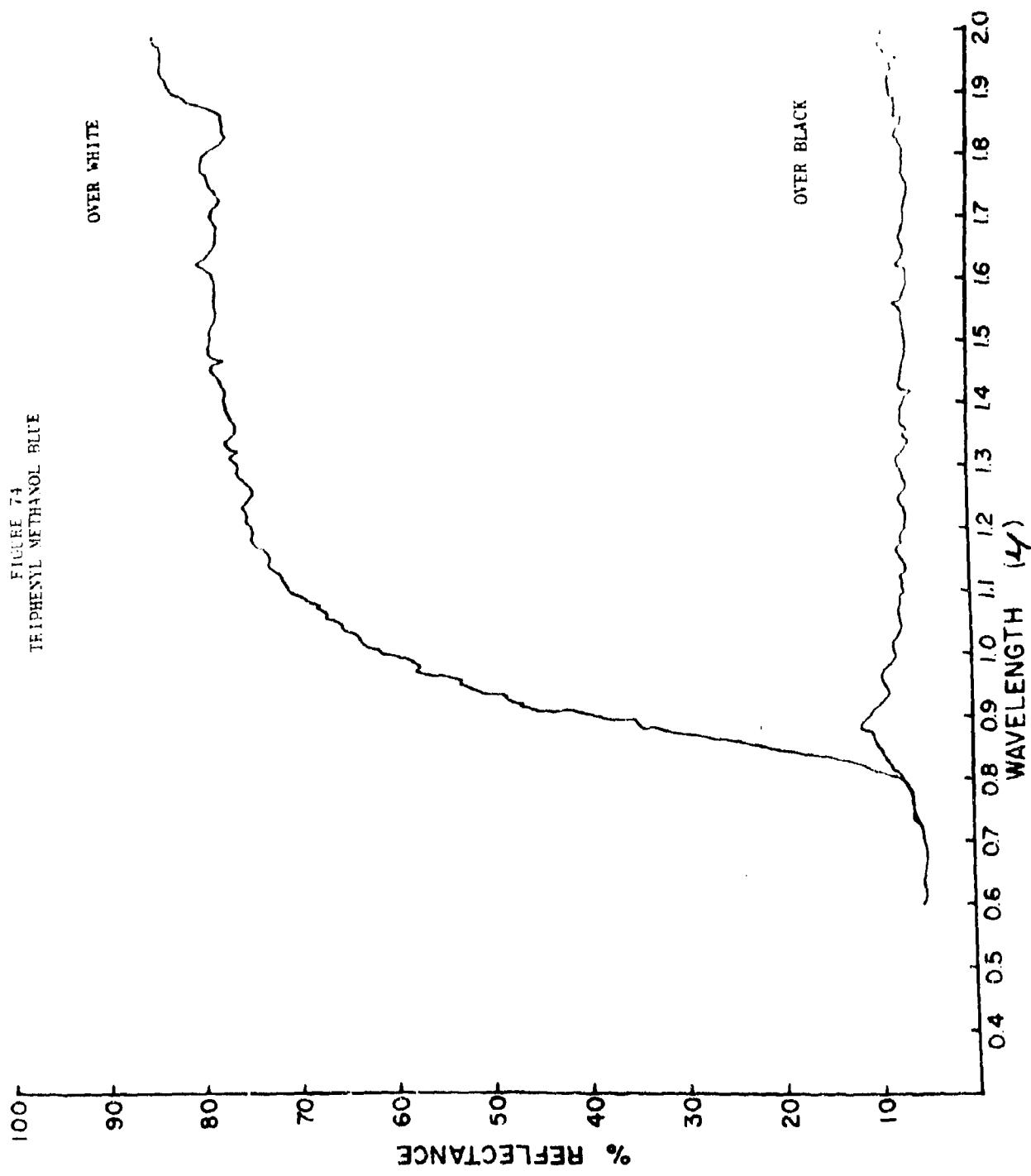


FIGURE 74  
TRIPHENYL METHANOL BLUE



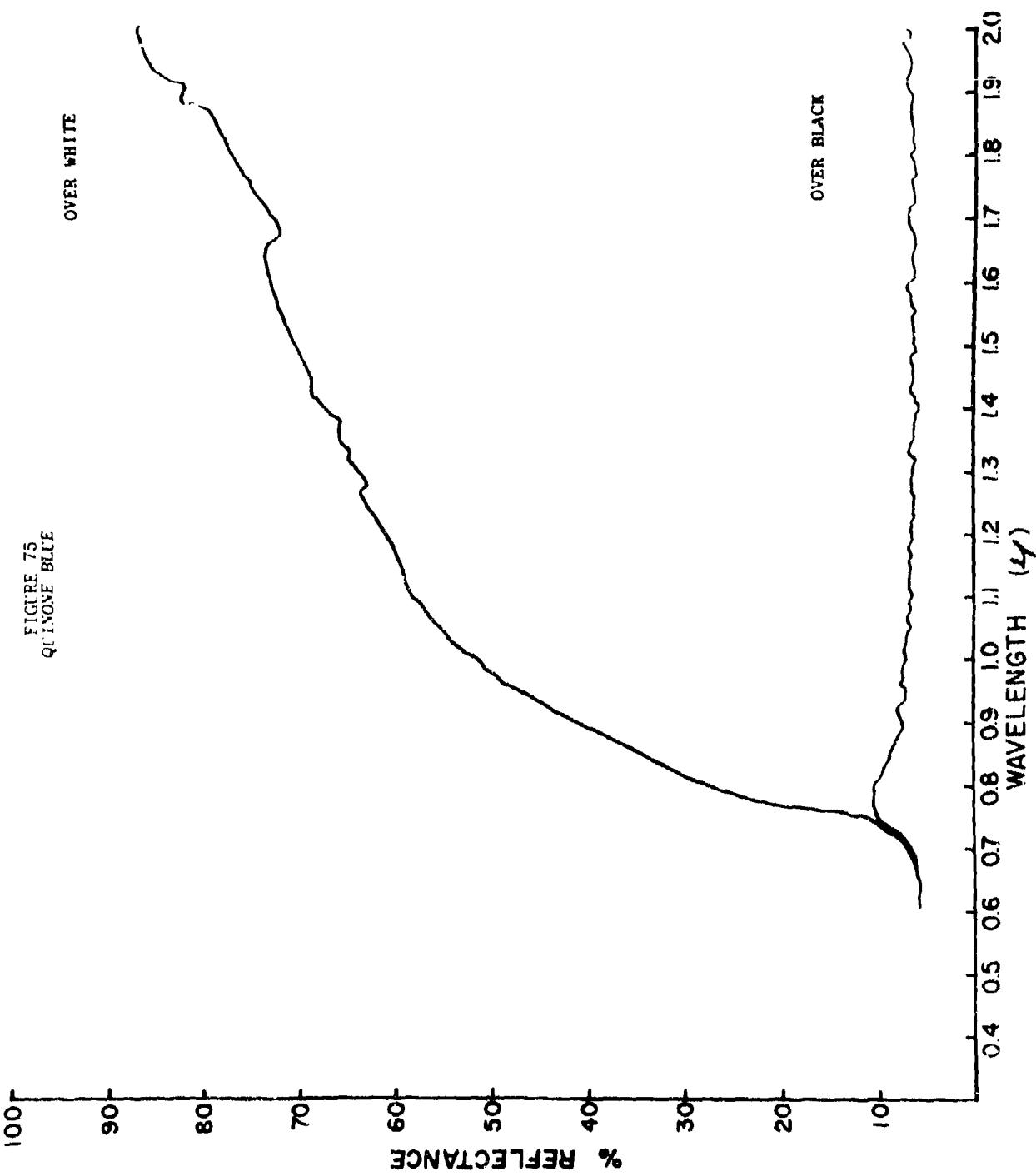


FIGURE 76  
PHOSPHOTUNGSTIC ACID BLUE

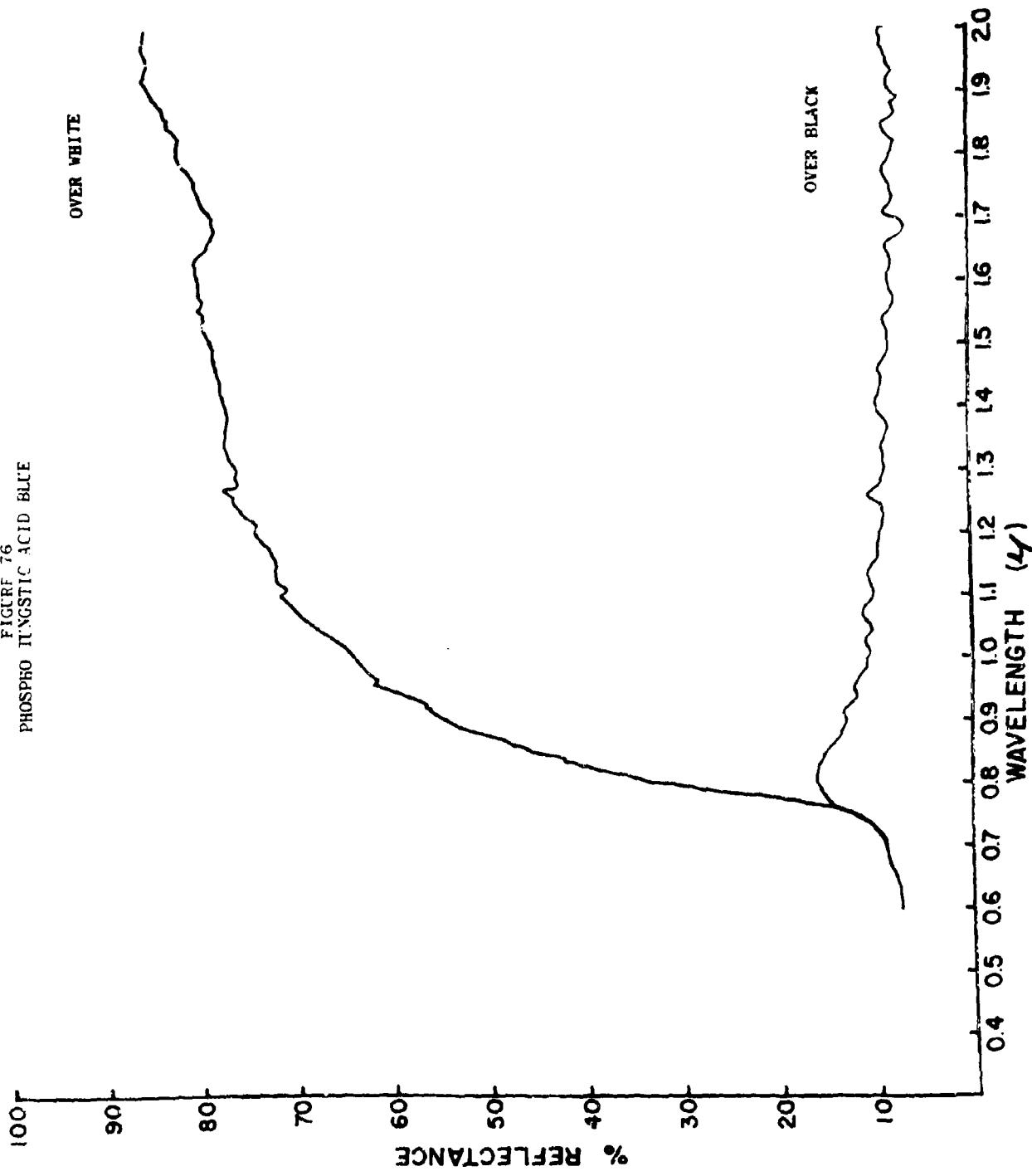


FIGURE 77  
METAL FREE PHTHALOCYANINE  
BLUE

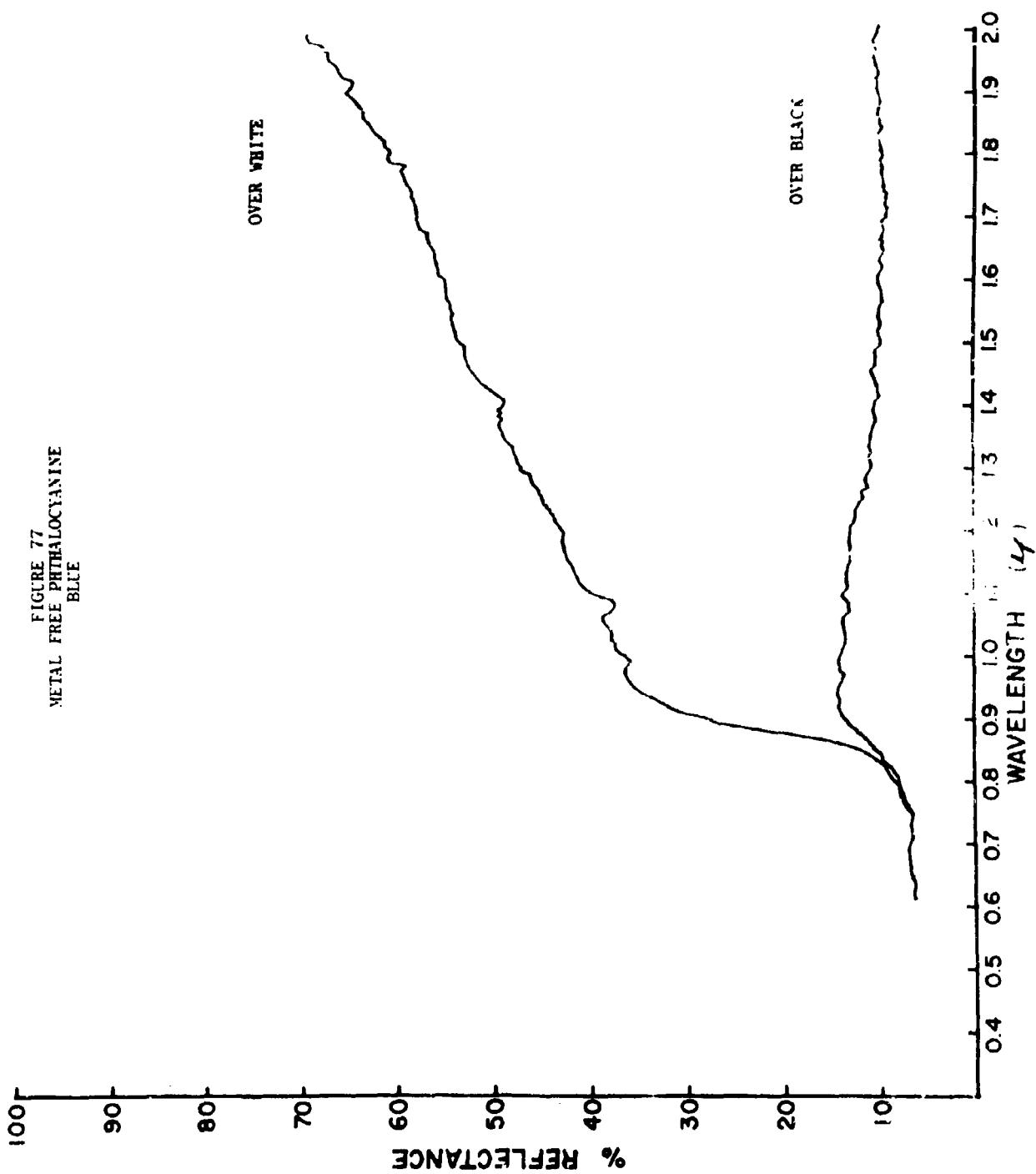


FIGURE 78  
COPPER PHTHALOCYANINE  
BLUE

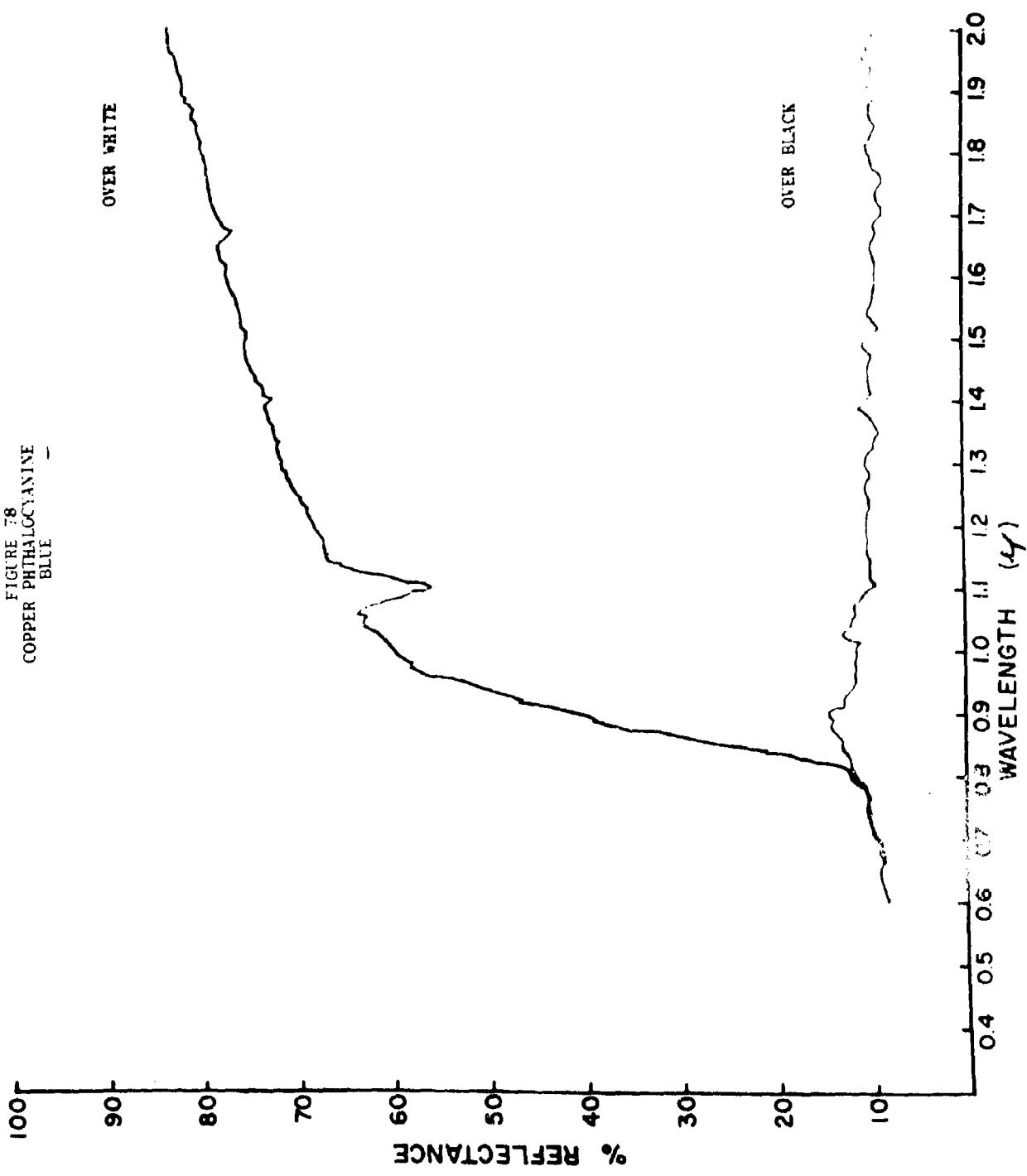


FIGURE 79  
COPPER PHTHALOCYANINE  
BLUE

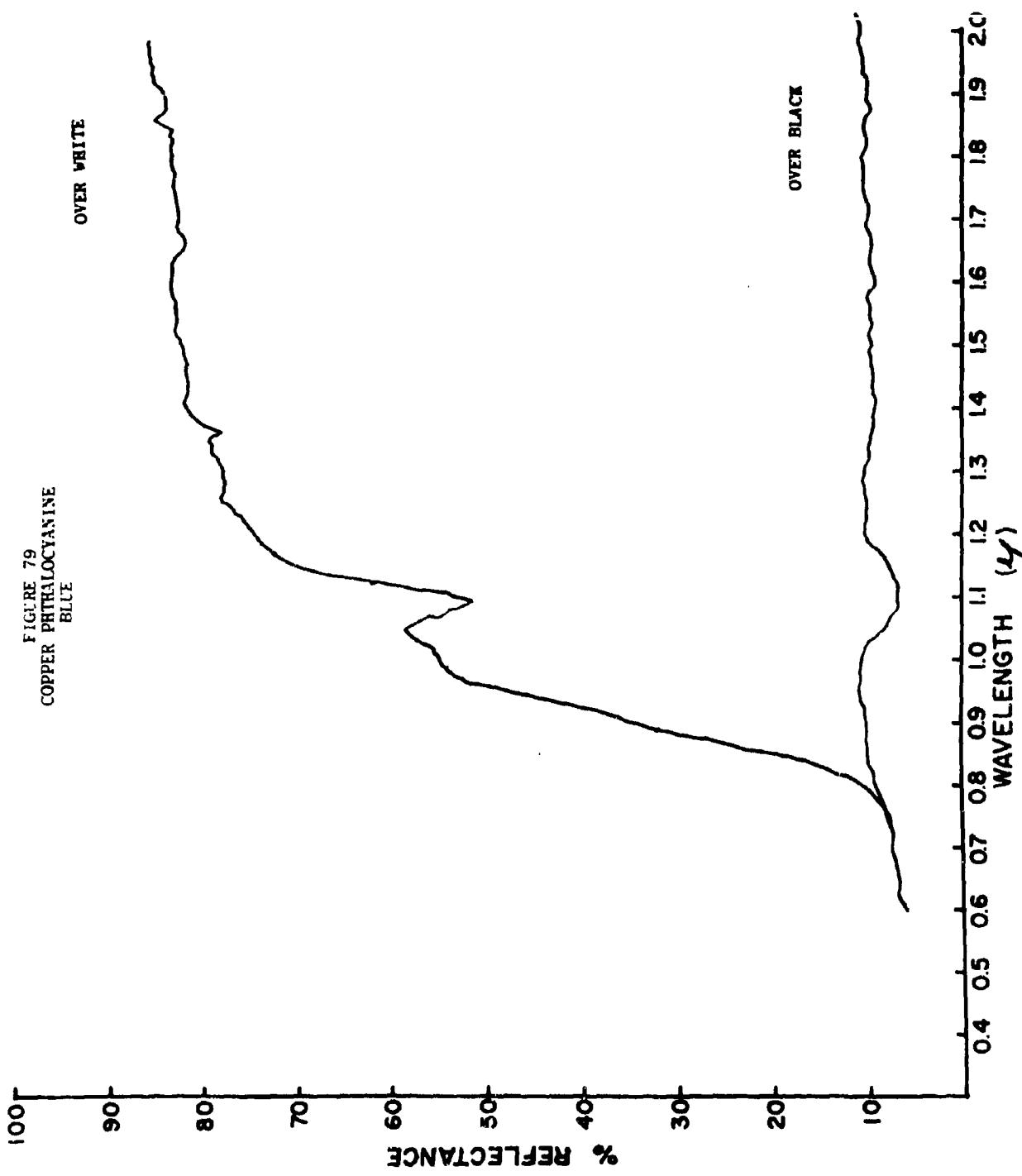


FIGURE 8D  
COPPER PHTHALOCYANINE  
BLUE

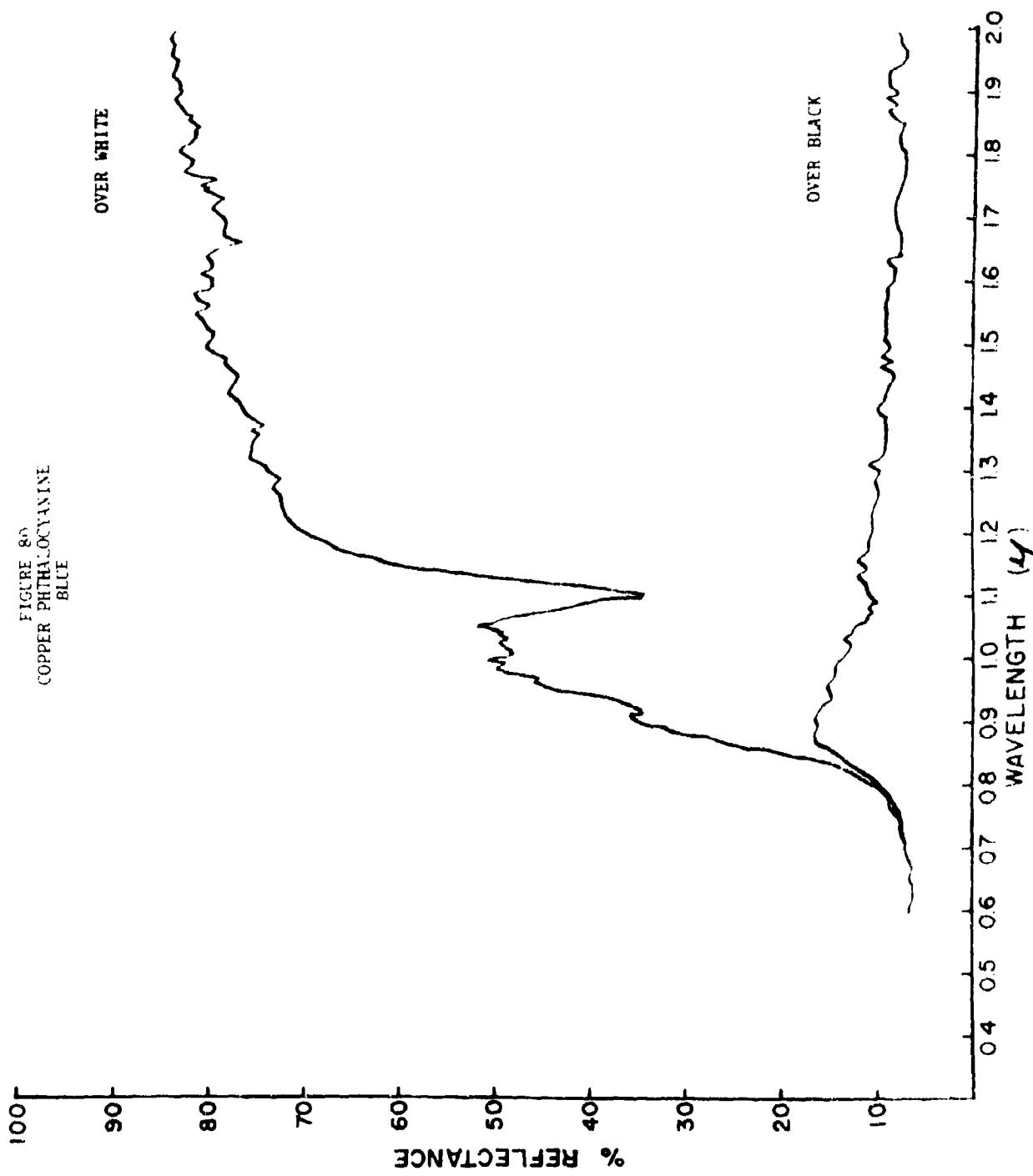
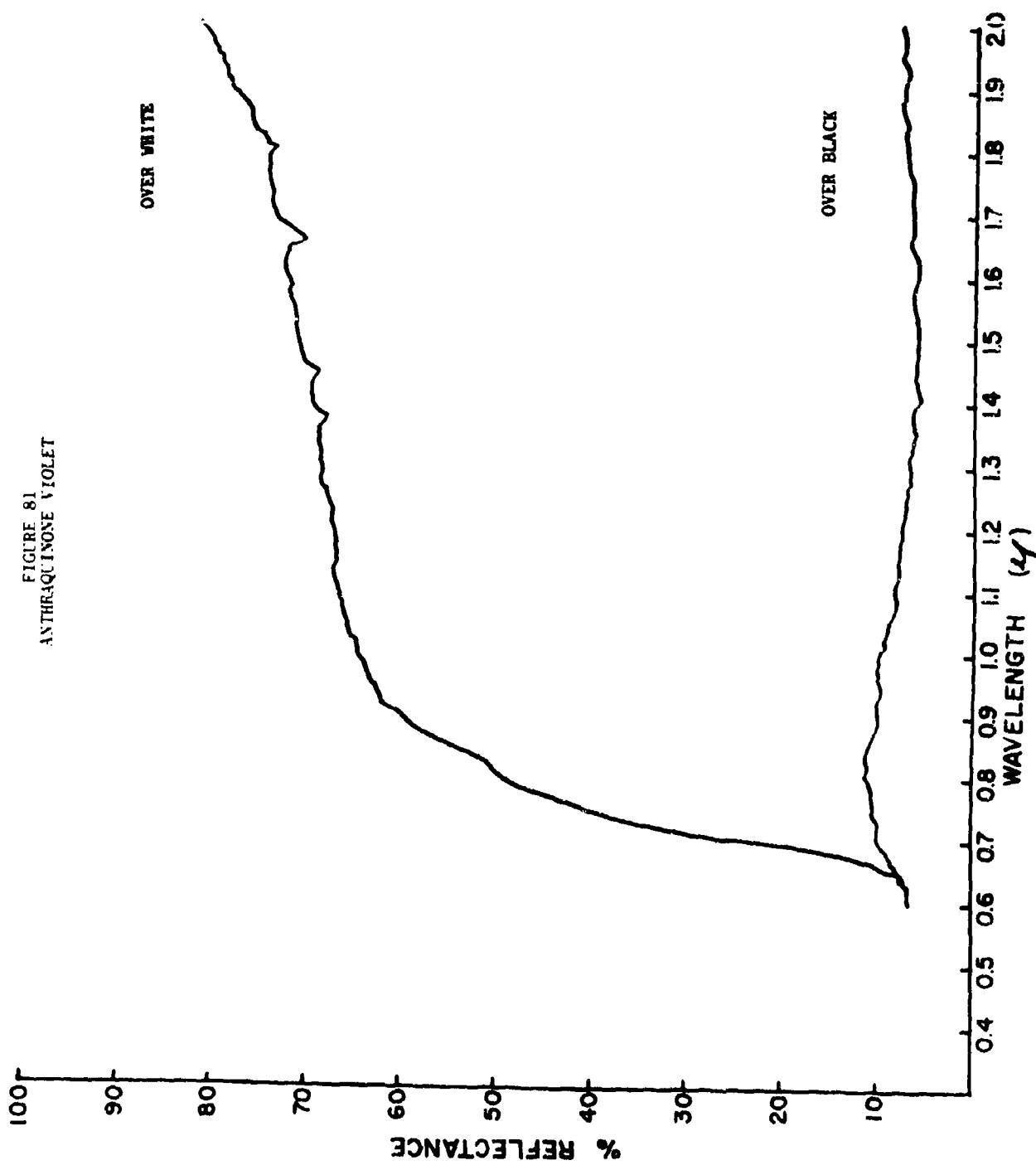


FIGURE 81  
ANTHRACIUSONE VIOLET



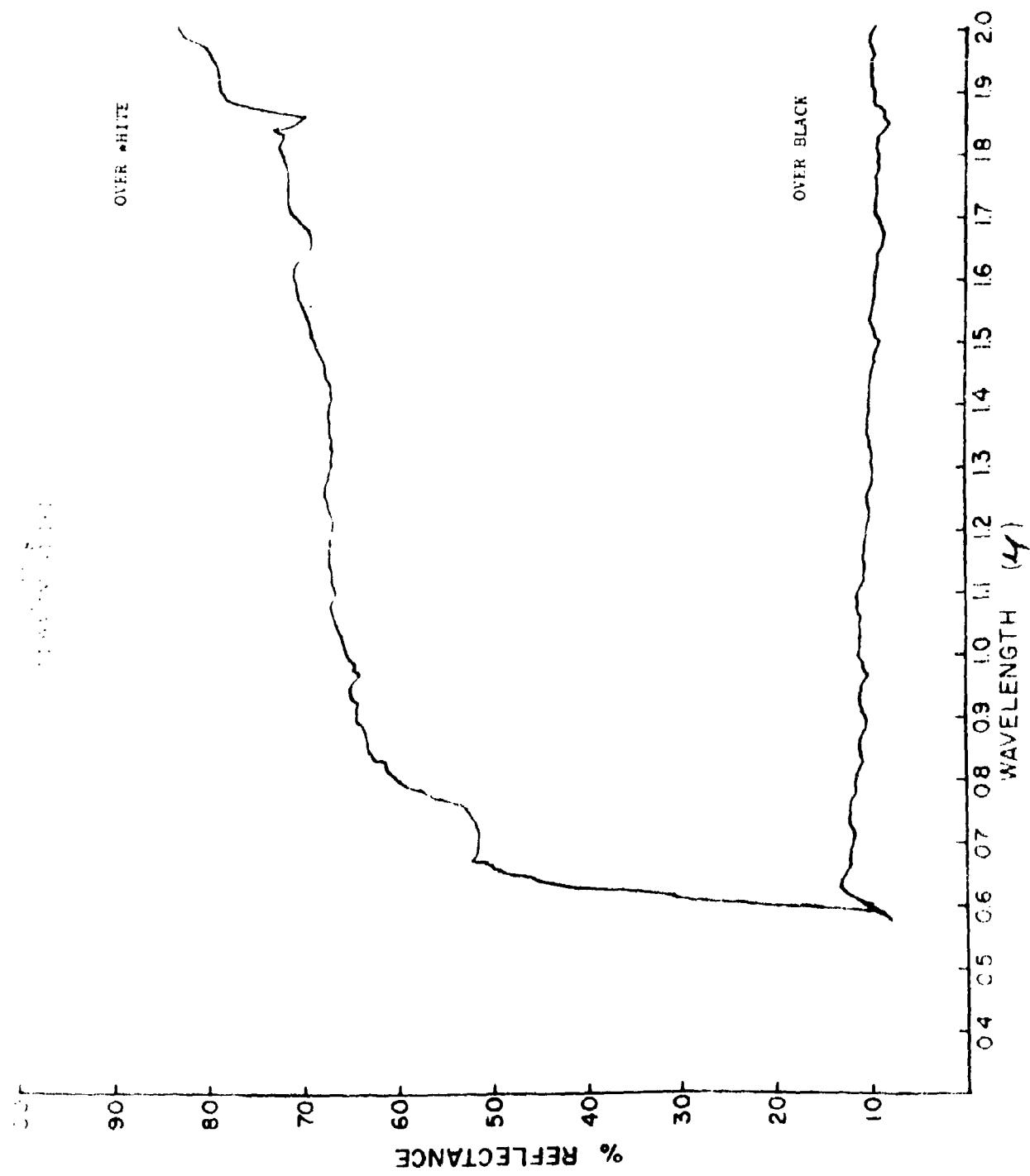


FIGURE 83  
DIOKAZINE VIOLET

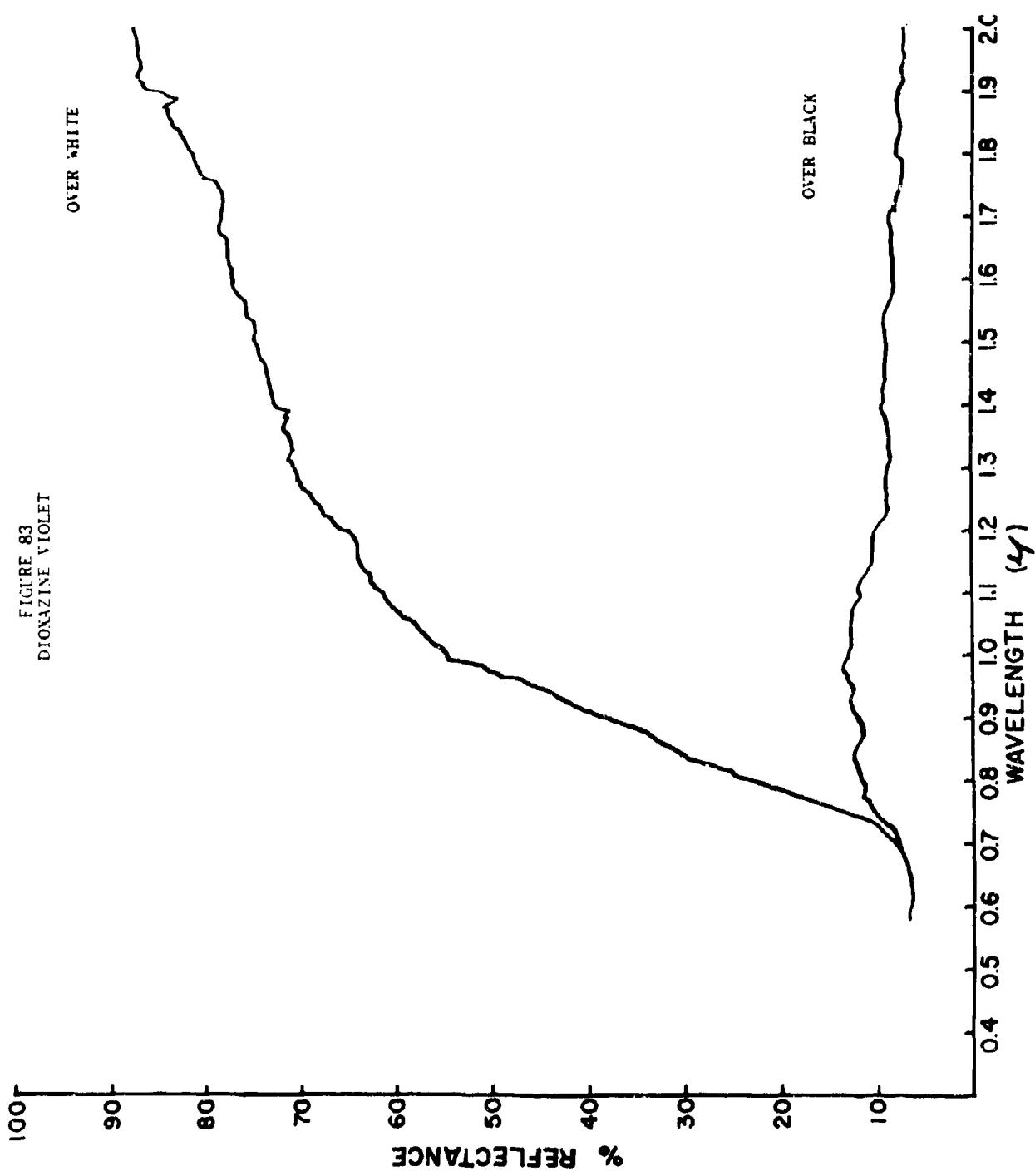


FIGURE 84  
REFLECTION CURVE

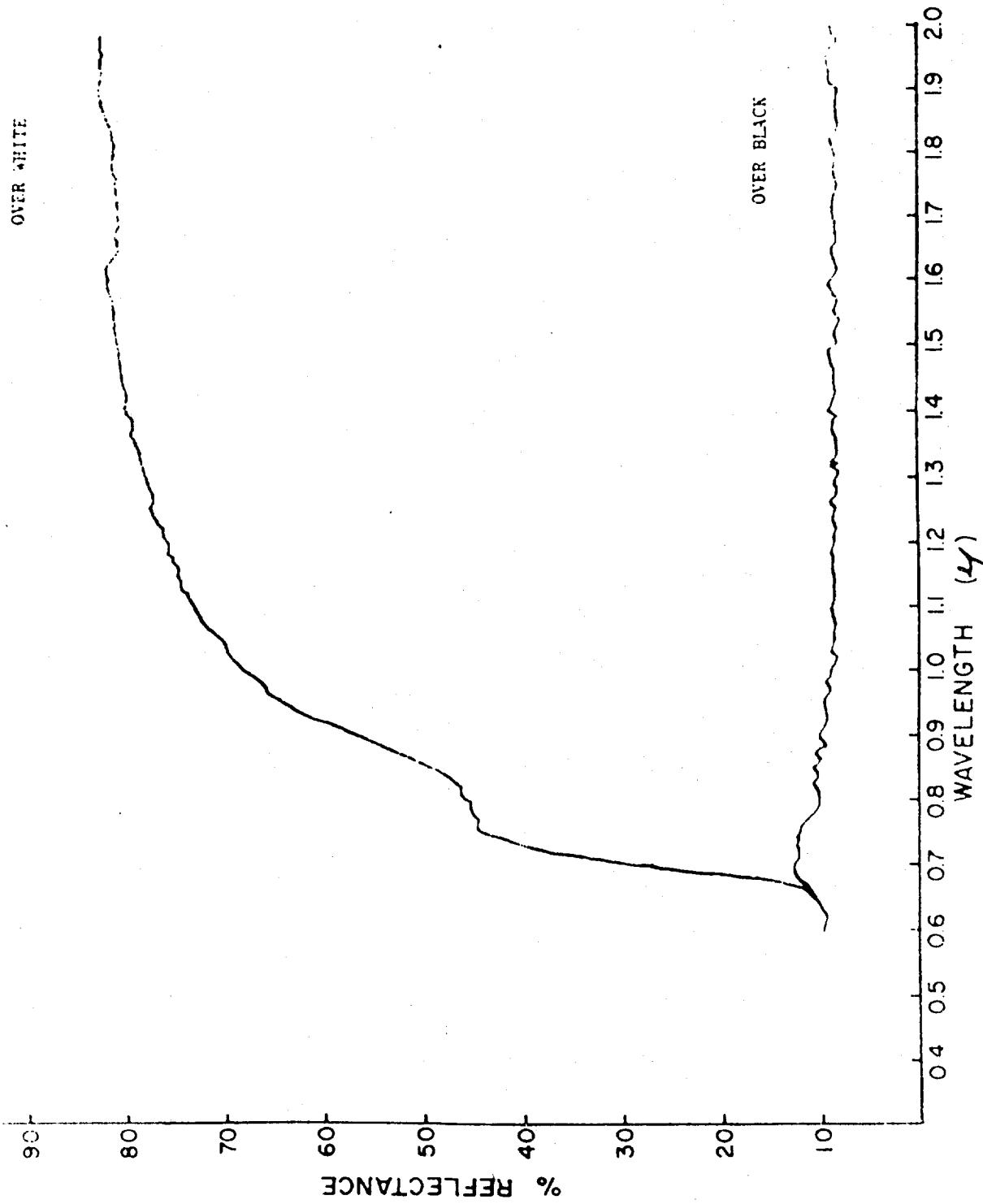


FIGURE 85  
INDIGO VIOLET

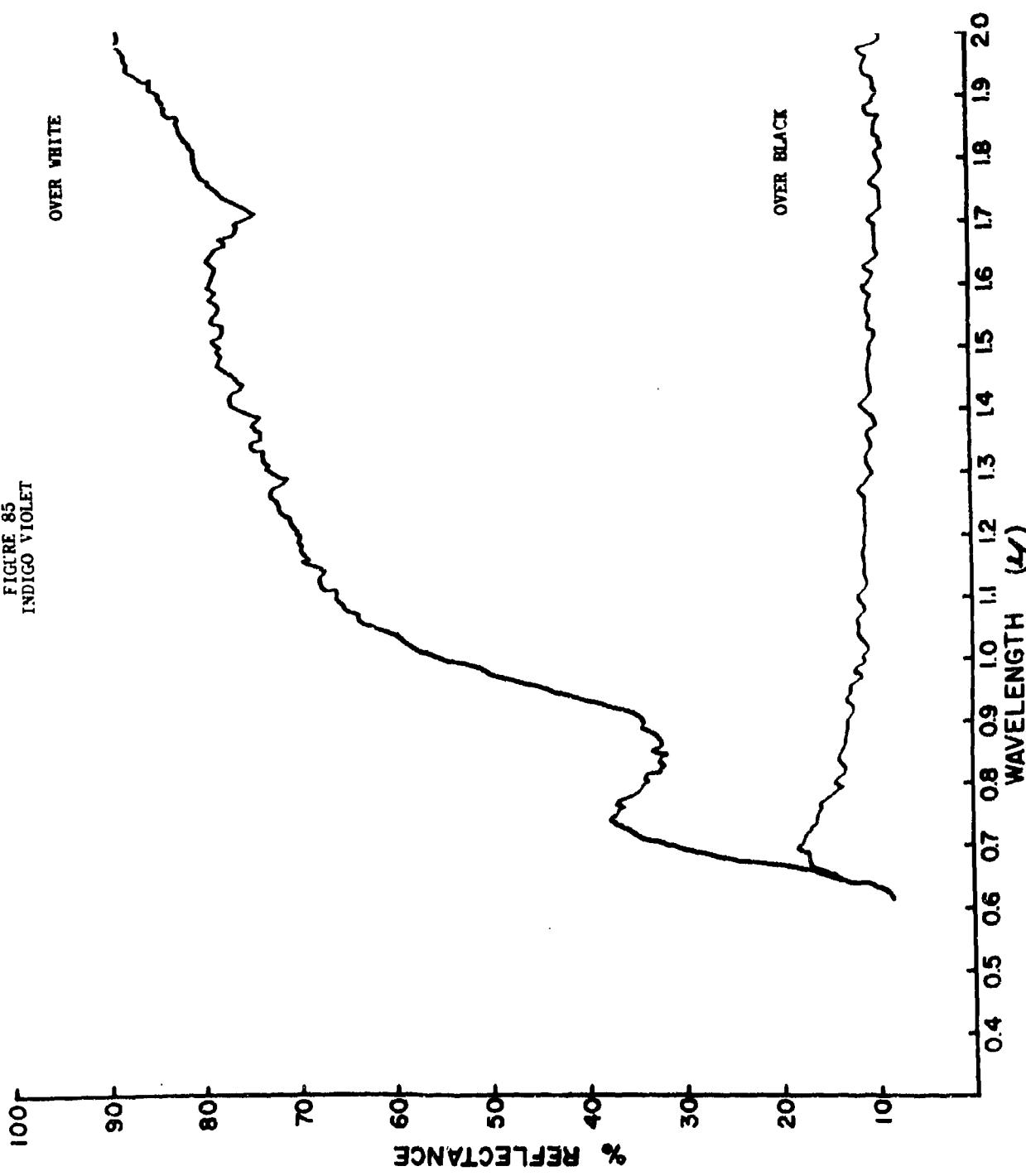


FIGURE 86  
VI THIN VIOLET

